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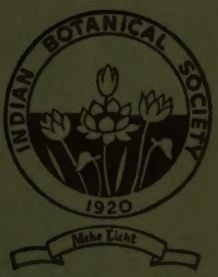
of

The Indian Botanical Society



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STUDIES IN CROP PHYSIOLOGY

Effects of N–P–K Ratios on Growth Characters of Barley

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(Received for publication on January 15, 1951)

Introduction

Recent studies on growth performance of crop plants (Costache, 1940; Thomas and Mack, 1940; Tyner, 1947) have shown that increased plant growth, intensity of nutrition and adequate physiological balance of nutrients are interrelated and that displacement in nutrient equilibrium markedly affects yield. Relatively, nitrogen exhibits greater effects on growth, while potassium and phosphorus follow in order (Lal and Pathak, 1948; Lal and Prasad, 1948; Singh, 1940, 1941). Adequate balance between nitrogen and phosphorus is claimed to result in good plant development, while wide variations in yield have been recorded with great displacement in nitrogen, phosphorus and potash equilibrium (Stanford *et al.*, 1941; Thomas and Mack, 1940, 1941 *a*, 1941 *b*, 1943).

Plant response to different ratios varies with the time when fertilisers are made available. Thus changes in N/K ratios do not materially alter grain yield if the elements are supplied at shooting. Potassium increases grain of barley if applied before heading; at shooting yield is reduced. Association of potassium and nitrogen before sowing in adequate doses has been found to be helpful (Alov, 1944). A reciprocal relation between potassium and calcium and magnesium is also suggested. Varying ratios of major elements also influence production in artificial cultures (McCall and Woodford, 1938; Singh, 1940).

The extent to which applied fertilisers affect absorption and utilisation of elements is also suggested to determine growth performance of different species (Beckenback, 1938; Craig, 1939 and 1941; Dutoil and Beater, 1939; Lundegårdh, 1951; Murneek and Gildheaus, 1931; Norem, 1936; Thomas and Mack, 1933). The concepts of poverty adjustments and luxury consumption have been put forth to explain this relationship (Macy, 1936). For balanced growth where quality and quantity both need to be blended, it is desired to use mixed fertilisers in adequate ratios (Murphy, 1945), and apply them at a time when plants could utilise them to their maximum advantage. Lack of balance as a rule, is more detrimental for growth than deficiency of nutrients.

The question, therefore, arises as to how far nitrogen, phosphorus and potassium affect growth characters and yield and to what extent plant response to the conditions of differential feeding may be explained in terms of general physiology of barley plant. This paper is an attempt to explore some of the basic factors involved in the nutrition of the barley plant in relation to (i) supply of elements and (ii) the state of physiological salt balance in the culture medium.

Procedure of Experiment

A. *Preparation of pot culture.*—The investigations were conducted on barley variety C 251, grown in cement concrete pots each filled with 60 lb. of farm soil (sandy loam). About 25 seeds of barley were sown in each pot in November 1948. Thinning was done a week after germination to reduce the number of plants to six per pot. All care was taken to maintain a culture free from weeds and provide adequate quantities of water to meet the demands of the growing shoot. Regular hoeing of the surface soil was done to ensure aeration.

When the plants were twenty days old, a mixture of pure ammonium sulphate, potassium hydrogen phosphate and sulphate of potash in varying ratios of N–P–K but with a total salt concentration of 80 ppm. by weight of dry soil was applied. Twenty-one combinations of these nutrients provided different degrees of nutrition to the plant as indicated in Table I.

The quantity of nutrients corresponding to the above dosage was calculated and supplied to each culture directly. This was done in one instalment when the plants were 25 days old. Sufficient quantity of water was added to dissolve the nutrients so supplied to enable them to be adequately distributed in the vicinity of the absorbing zone in the top five inches of soil.

B. *Characters recorded.*—Records of growth characters were begun 25 days after fertilisation and recorded at 50, 68 and 86 days in the life-cycle of the plant. At each of these stages measurements were taken of (i) height of main shoot, (ii) number of tillers, (iii) number of leaves on main shoot, and (iv) length and breadth of fully expanded leaf, and lastly (v) fresh and dry weight of all the component parts, *e.g.*, root, stem, leaves and ears at the final stage. Records of the external growth characters were taken on three plants selected at random from each culture.

C. *Statistical analysis and presentation of data.*—Average figures for the characters were examined statistically to evaluate the effects of (i) stage of plant development and (ii) nutrient ratios. Interaction between these two factors, namely, age $\times$ nutrient ratio was also determined by analysis of variance method. Relative effect of different ratios were also examined to find out a physiologically balanced condition of N–P–K nutrition for the barley plant. The ratio between different characters such as height/tiller and length/breadth of leaf was also calculated to illustrate the nature of the response.

Finally the observations on different growth characters were examined in relation to (i) the quantity of total nutrition provided to

the plant and also (ii) the proportion that each of the three nutrients exhibited to the total concentration supplied in the culture medium. How far intensity and quality of nutrition determined the performance of this plant from the point of view of vegetative and reproductive growth has been elucidated in detail. Graphical representation of the responses have also been given wherever necessary. In most cases, statistical analysis of the data has been done; relevant data pertaining to these observations are presented in the text figures.

Experimental Findings

Effect of nutrient ratios on height of main shoot.—Considerable variations in height of main shoot were noticeable in response to different ratios of fertilisers. Treatment effects were highly significant (Table II *a* and II *b*). Age effects and interaction between age and treatment, both were significant. Mean values for height at different stages showed that age increased height; differences between first and second stage were of greater magnitude than differences in height between second and third stage. Maximum average height was recorded under $N_{20}P_{40}K_{20}$ while minimum height was noted under $N_{10}P_{20}K_{50}$.* Other treatments showing favourable effects on height at 86 days were: $N_{60}P_{10}K_{10}$, $N_{50}P_{20}K_{10}$, $N_{40}P_{20}K_{20}$, $N_{30}P_{10}K_{40}$, $N_{10}P_{40}K_{30}$ and $N_{20}P_{20}K_{40}$. Differences amongst these treaments and others showing poor height were highly significant.

Effect of nutrient ratios on leaf number.—Number of leaves on the main shoot again, was significantly affected by both age and treatments. Interaction between age and treatments also showed significant effects (Table III *a* and III *b*). Advance in age of plants upto 68 days resulted in increased production of leaves. Subsequently, leaf number did not alter markedly with age. Variations amongst different treatments at the final stage were also recorded with a minimum under $N_{10}P_{10}K_{60}$ and a maximum under a ratio of $N_{30}P_{40}K_{10}$. Differences between these two treatments were highly significant. Majority of treatments having favourable effect on leaf number differed significantly from those showing poor leaf number.

Effect of nutrient ratios on tillering.—Number of tillers was significantly affected by both age and treatments. Interaction between these two was, however, insignificant (Table IV *a* and IV *b*). Advance in age upto 68 days raised tiller number significantly irrespective of the treatment given to the plants. Further advance in age showed mortality of shoots as a result of which tillering was reduced. Occasionally due to favourable conditions, shoots survived and the number was maintained. High tillering at 86 days was recorded under $N_{60}P_{10}K_{10}$, $N_{30}P_{40}K_{10}$, $N_{10}P_{40}K_{30}$, $N_{40}P_{20}K_{20}$, $N_{40}P_{30}K_{10}$ and $N_{30}P_{30}K_{20}$. These nutrient combinations as a group differed significantly from those exhibiting poor tillering. Differences amongst individual treatments were also occasionally significant.

Nutrient effects upon leaf length.—Age and treatments both showed significant effects upon the leaf length. Interaction between these

* Figures at the base of N, P, K indicate levels in parts per million.

two factors was significant (Table V *a* and V *b*). Advance in age upto 68 days improved leaf length, while further increase to 86 days lowered leaf length slightly. In majority of the ratios, the average length of leaf at 86 days was higher than 7 cm. while only in few cases lower leaf sizes were recorded. The latter was the case under $N_{10}P_{10}K_{60}$, $N_{10}P_{20}K_{50}$, $N_{10}P_{50}K_{20}$, $N_{10}P_{60}K_{10}$, $N_{50}P_{10}K_{20}$ and $N_{20}P_{20}K_{40}$. In all these cases depressing effects upon leaf development were significant when compared with favourable ratios of $N_{20}P_{40}K_{20}$, $N_{40}P_{20}K_{20}$, $N_{30}P_{20}K_{30}$, $N_{50}P_{20}K_{10}$ and $N_{30}P_{30}K_{20}$.

Nutrient effects upon leaf width.—Breadth of leaf was significantly affected by age and treatments and age × treatment interaction (Table VI *a* and VI *b*). The greater the age, the wider was the breadth of leaf. This was true for majority of the treatments under consideration. In some cases only, differences between the second and third stages were either negative or negligible. Greater width of leaves was recorded at 86 days under nutrient ratios of $N_{60}P_{10}K_{10}$, $N_{30}P_{20}K_{30}$, $N_{40}P_{10}K_{30}$, $N_{50}P_{20}K_{10}$, $N_{40}P_{20}K_{20}$, and $N_{20}P_{40}K_{20}$, while other ratios for instance, $N_{10}P_{10}K_{60}$, $N_{10}P_{20}K_{50}$, $N_{10}P_{60}K_{10}$, $N_{10}P_{50}K_{20}$, $N_{20}P_{50}K_{10}$ and $N_{10}P_{40}K_{30}$ showed poor leaf width. Differences amongst these two groups of ratios were statistically significant.

Nutrient effects upon length/breadth ratio in leaves.—Wide variations in length/breadth ratio were noted in response to the treatments applied (Table VII). Fairly low ratio of L/B was recorded at 86 days under $N_{10}P_{50}K_{20}$, $N_{20}P_{20}K_{40}$, $N_{50}P_{10}K_{20}$, $N_{10}P_{20}K_{50}$, $N_{40}P_{10}K_{30}$ and $N_{30}P_{10}K_{40}$; in contrast to these, high length/breadth values were recorded under $N_{10}P_{60}K_{10}$, $N_{20}P_{40}K_{20}$. $N_{10}P_{40}K_{30}$, $N_{20}P_{50}K_{10}$, $N_{30}P_{30}K_{20}$, and $N_{20}P_{30}K_{30}$. Under the latter ratios, the nutrition provided favoured the development of leaf length more in proportion to leaf width. No fixed proportion of any of these ingredients for inducing high values of length in proportion to width was noticeable. Wide variations in nutrient concentration were equally efficient in inducing high length/breadth ratio.

Nutrient effects upon height/tiller ratio.—This ratio is again influenced by age and condition of nutrition. The higher the age the greater was the ratio (Table VII). No consistent effects were noticeable in the sense that a ratio most favourable from the point of view of this character at one stage did not necessarily prove equally efficacious at other stages of life-cycle. Average, figures for the third stage, however, indicate the efficiency of the following ratios of nutrients in improving height/tiller ratio: $N_{20}P_{20}K_{40}$, $N_{10}P_{50}K_{20}$, $N_{50}P_{10}K_{20}$, $N_{50}P_{20}K_{10}$, $N_{30}P_{10}K_{40}$, and $N_{40}P_{10}K_{30}$; Other treatments causing marked reduction in this ratio were: $N_{40}P_{30}K_{10}$, $N_{30}P_{40}K_{10}$, $N_{10}P_{20}K_{50}$, $N_{10}P_{10}K_{60}$, $N_{30}P_{30}K_{20}$, and $N_{10}P_{40}K_{30}$. No consistency in response has been noted at different stages of the life-cycle.

Relative effects of N : P ratios on growth characters.—The effect of N/P ratio was studied under two conditions of potassium nutrition, namely, low potassium (10 ppm.) and medium potassium (30 ppm.) on such characters as dry weight, leaf number, height and tillers. Increasing ratio of N/P showed a marked effect under N/P ranges of

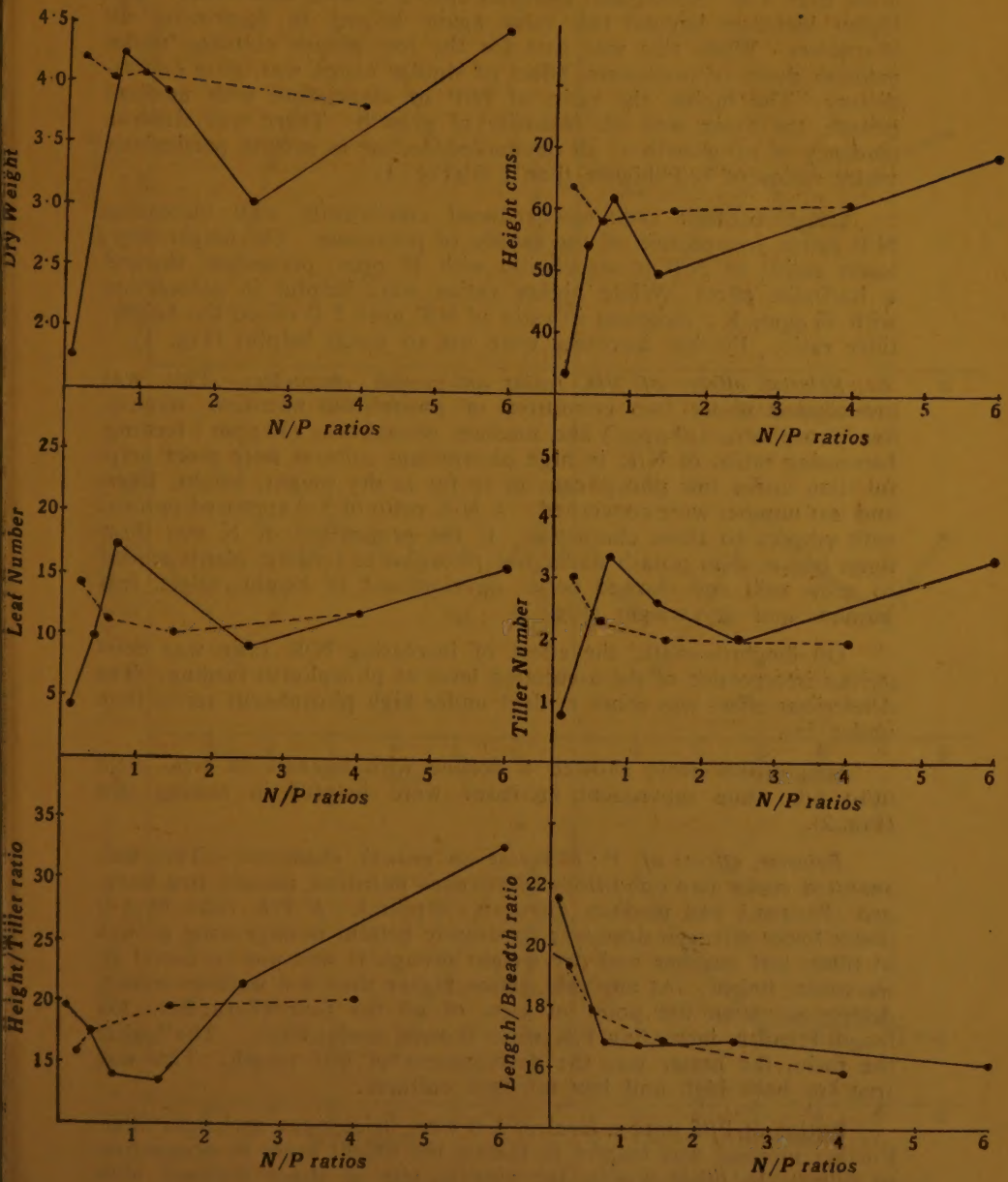


FIG. 1. Effect of N/P ratios upon growth characters of barley. Continuous line — Low potash series; discontinuous line — medium potash series.

more than 1·0. Subsequent increases upto 2·5 were deleterious. Still higher increases beyond this value again helped in improving all characters. While this was true for the low potash cultures, under medium doses of potassium, effect of similar ratios was quite contradictory. The higher the ratio of N/P in association with medium potash, the lower was the intensity of growth. There was either a tendency of no growth at all or marked decline in growth particularly under ratios of N/P higher than 2·0 (Fig. 1).

Length/breadth ratio was reduced consistently with increasing N/P ratios irrespective of the supply of potassium. On height/tiller, lower ratios of N/P in association with 10 ppm. potassium, showed a harfmful effect. While higher ratios were helpful in association with 30 ppm. K; increases in ratio of N/P upto 2·0 raised the height/tiller ratio. Further increases were not so much helpful (Fig. 1).

Relative effects of N/K ratios on growth characters.—This was investigated under two conditions of phosphorus nutrition, namely, low phosphorus (10 ppm.) and medium phosphorus (30 ppm.) feeding. Increasing ratios of N/K in high phosphorus cultures were more helpful than under low phosphorus in so far as dry weight, height, tillers and leaf number were concerned. A N/K ratio of 3·0 appeared optimal with respect to these characters. If the proportion of N was three times higher than potash under low phosphorus feeding, plants tended to grow well and showed better development of height, tillers, leaf number and dry weight (Fig. 2).

On length/breadth, the effect of increasing N/K ratio was deleterious irrespective of the associated level of phosphorus feeding. The deleterious effect was more evident under high phosphorus series than under low.

Height/tiller ratio showed a decline with increase in N/K ratio upto 4·0 while subsequent increases were helpful in raising this (Fig. 2).

Relative effects of P : K ratios on growth characters.—This was analysed under two conditions of nitrogen nutrition, namely, low nitrogen (10 ppm.) and medium nitrogen (30 ppm.). A P/K ratio of 4·0 under lower nitrogen dose was apparently helpful in improving growth in tiller, leaf number and dry weight though it was not so useful in increasing height. At any rate, ratios higher than 4·0 were invariably deleterious from the point of view of all the four characters. On length/breadth, increasing P/K ratio showed useful effect. The higher the ratio, the better was the development of leaf length. This was true for both high and low nitrogen cultures.

Ratios of P/K upto a level of 3·0 were deleterious on height/tiller. Further increase was helpful in raising the height more in proportion to tillers. In other words, the average size of shoot declined with lower ratios of P/K and increased with higher values of this ratio. A P/K ratio of 3·0 was considered to be the critical limit when minimum values for height/tiller were recorded (Fig. 3).

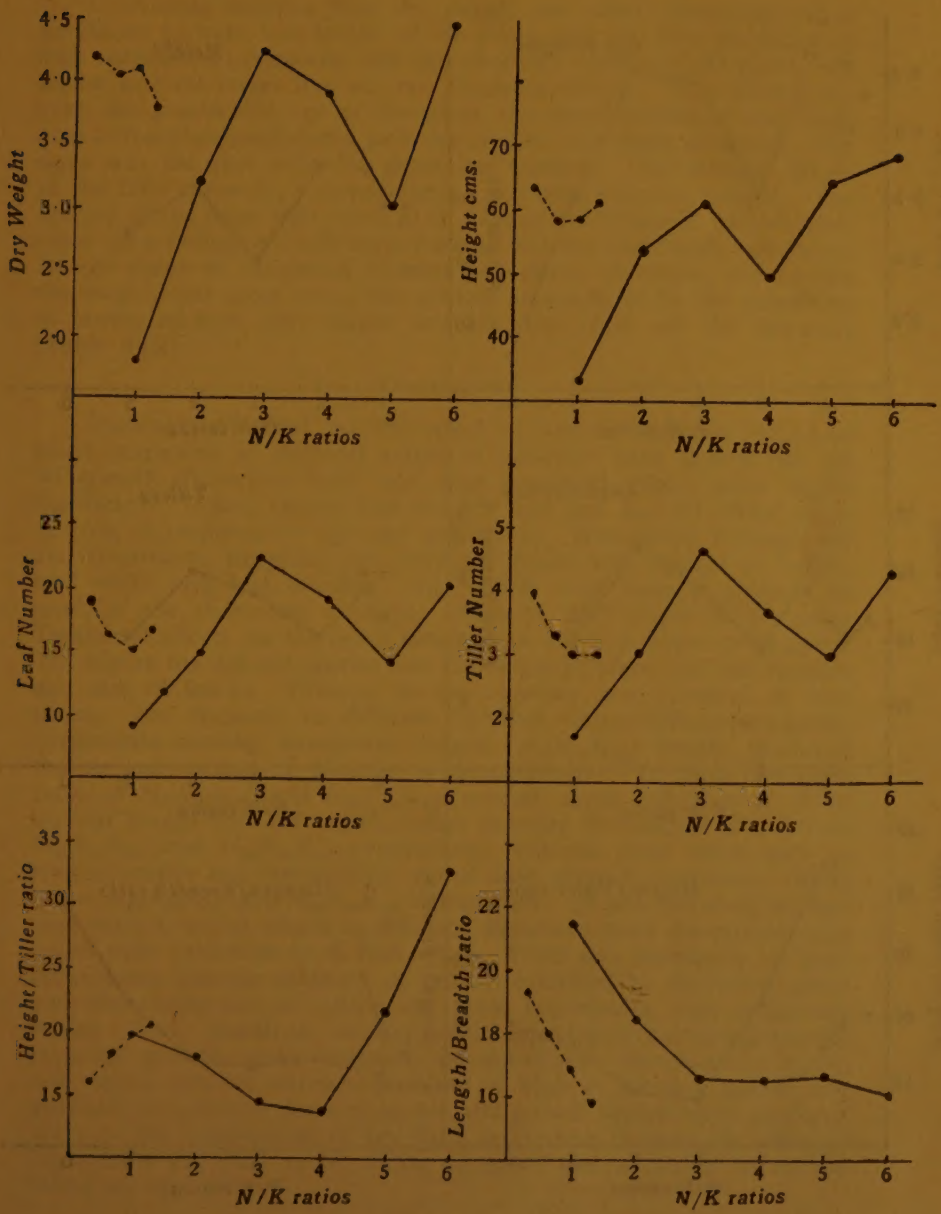


FIG. 2. Effect of various N/K ratios on growth characters of barley. Continuous line — Low phosphorus series; discontinuous line — medium phosphorus series.

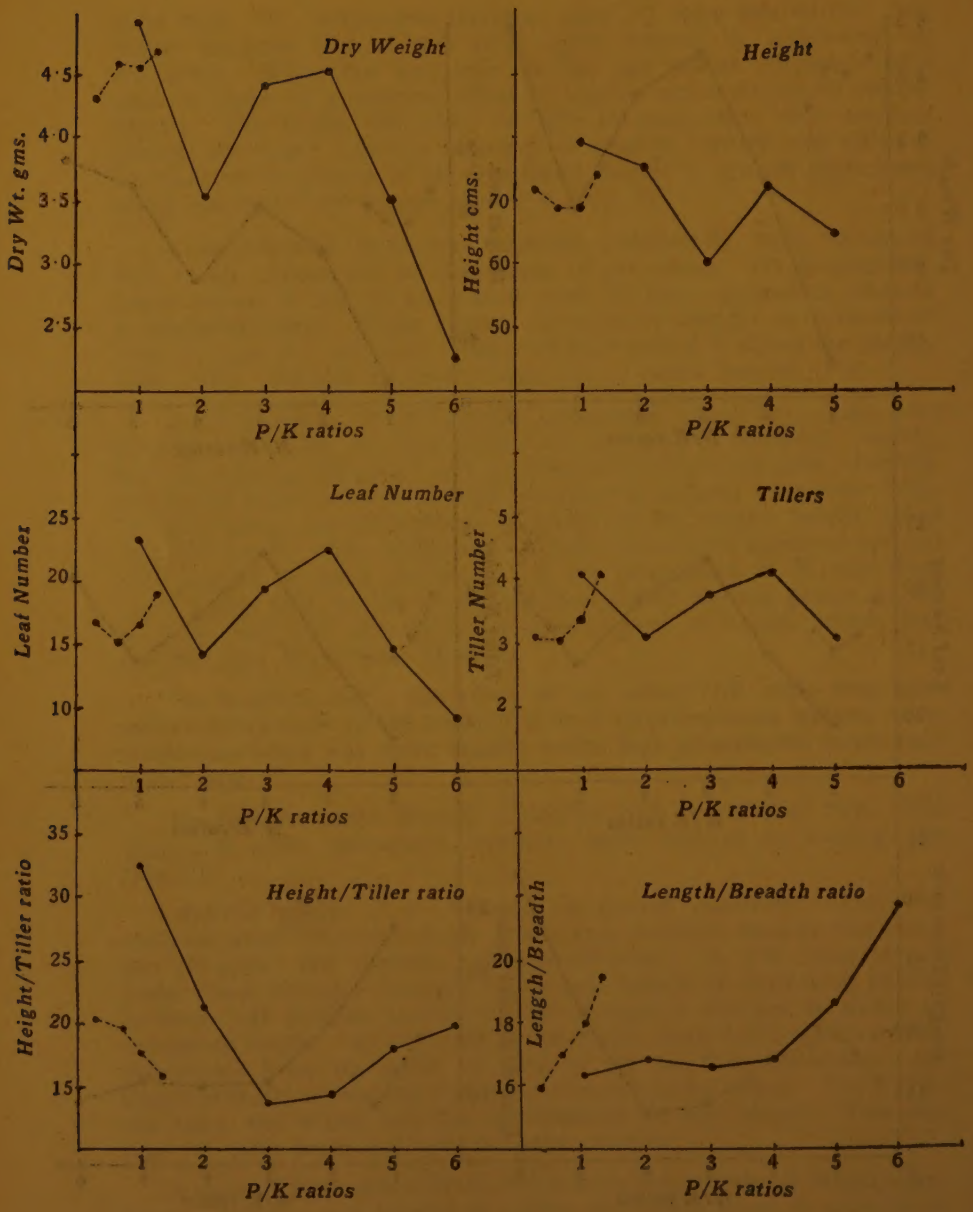


FIG. 3. Effect of various P/K ratios on growth characters of barley. Continuous line — low nitrogen series; broken line — medium nitrogen series.

Correlation between final dry weight and plant characters.—It is significant to note that height of the plant after 68 days showed very high correlation coefficient with the total dry weight of the plant. At earlier or later stages this was not so characteristic. With tillers however, the greater the age of the plant, the more significant and fairly high correlation coefficients with dry weight have been observed. The same was the case with the green leaf number. The average height of the tiller however, was negatively correlated with dry weight. Significant values were only noted at 68 days in the life-cycle. In all other cases the correlation coefficients were all positive and highly significant. At the stage of maximum tillering (68 days), therefore, the smaller the height/total shoot ratio, the greater appeared to be the possibility of producing high dry weight towards the close of the life-cycle (Table VIII).

Discussion

Evidences collected on the effect of various nutrient ratios on plant characters at different stages of life-cycle have shown that on all growth characters both age and treatment effects were highly significant. Tillers, height, leaf number and leaf size all varied significantly in response to age and treatments. Interaction between age and treatments, however, was only significant with respect to height, leaf width and leaf number. Age effects were usually positive on most of the characters excepting tillers at later stages of life-cycle. Treatment effects on the other hand, were either positive or negative. The higher the age the greater was the height of plant and leaf number and size of leaves. Tillering on the contrary, was lowered at later stages. The response to different fertiliser ratios differed markedly. Treatments causing maximum height ($N_{20}P_{40}K_{20}$) hardly produced the highest number of tillering, or green leaves. In these two cases ratio of $N_{30}P_{40}K_{10}$ and $N_{60}P_{10}K_{10}$ proved more efficacious. Even on leaf length and leaf width, ratios showing favourable effects were $N_{20}P_{40}K_{20}$ and $N_{60}P_{20}K_{10}$ respectively. Various plant ratios such as length/breadth and height/tiller ratios also showed maximum values under $N_{10}P_{60}K_{10}$ and $N_{20}P_{20}K_{40}$ respectively. It was therefore evident that equally useful effects in different directions were discernible even under wide variations in N–P–K ratios. There was absolutely no fixed relationship between intensity of growth exhibited by the barley plant and the proportion in which the three ingredients were presented. Barley plant, therefore, showed wide capacity of exhibiting equally vigorous growth under extremes of nutritional conditions. It did not matter whether nitrogen was low or high or whether potash was available in sufficient quantity or not, the growth performance appeared more or less independent of any fixed proportion between the different ingredients provided each of the nutrients was available in certain minimum quantity.

Careful comparison of the data, however, indicated certain salient features of nutrient plant relationship. For instance the higher the ratio of N/P in association with medium potash the lower was the intensity of growth (Fig. 1). On length/breadth increasing N/P proved

consistently deleterious irrespective of the level of potash. Slight helpful effect of such increases in N/P ratio was noticeable on height/tiller as well. Similarly if the proportion of nitrogen was three times or more than potash particularly in association with low phosphorus level, plants showed tendency to grow well and exhibit better development in various directions (Fig. 2). On length/breadth and height/tiller ratios increasing N/K ratio was evidently harmful.

P/K ratios higher than 4·0 were invariably deleterious while lower ranges were occasionally helpful when associated with milder nitrogen levels (Fig. 3). The average size of the shoot declined under lower P/K ratios and increased under high values.

It, therefore, appeared that, if the proportion of nitrogen to phosphorus or to potash was not balanced properly harmful effect would be evident. There does not appear to be, however, any fixed ratio between these ingredients that may prove equally efficacious under all conditions of the experiment. Similarly it was not possible to allocate the importance of P/K ratio in any fixed manner. What caused variations in growth was something different from a mere proportional relationship between these ingredients. The relationship was occasionally casual and more frequently erratic with the result that growth performance in any direction could not be legitimately traced to any specific effect or relative proportion in which these ingredients were present in the external medium.

When analysed in terms of the total concentration of the medium and also the relative concentration of each ingredient in the total salt concentration, the dry weight of plant again did not show any fixed relationship (Table I and VII). Thus fairly high dry weight was recorded when the proportion of N in the culture medium varied between 12 and 75 per cent. of total salt concentration. Similarly the proportion of phosphorus and potash for high dry weight was found to be 12–50 per cent. and 12–37 per cent. of total salt concentration respectively. Here again the relative proportion of any ingredient in the culture medium hardly showed any fixed or narrow range within which high dry weight only could be obtained. Intensity of growth therefore appeared to be more or less independent of the total concentration of salts or the proportion that each individual ingredient exhibited towards total concentration. Differences in growth have therefore to be traced to other facts of metabolism relating to the proportion in which these ingredients might be present at the centres of metabolic activity rather than the external concentration in which they are presented in the culture medium.

From the point of view of vegetative and reproductive growth as estimated by the weight of grain and straw produced at harvest, the effect of nutrition appeared significant (Fig. 4). Irrespective of high or medium potash levels an increasing N/P ratio was helpful in improving the weight of grains per plant. For better reproductive growth therefore a slightly higher proportion of nitrogen compared with phosphorus was more helpful. On vegetative growth, however, the effects were characteristically deleterious under low potash feeding.

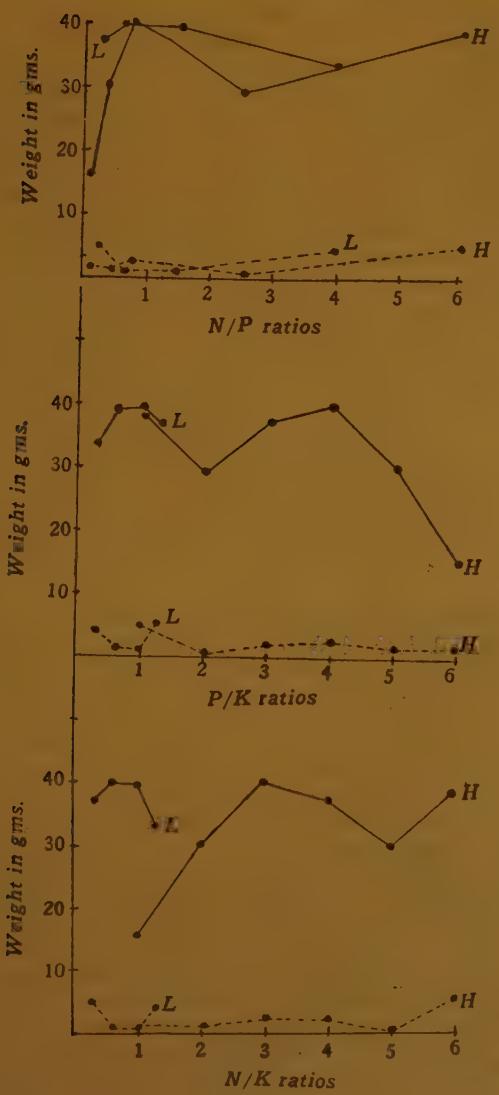


FIG. 4. Effect of N/P, P/K and N/K ratios upon vegetative growth (continuous line) and reproductive growth (discontinuous line) of barley under (H) High and (L) Medium levels of K, N and P respectively.

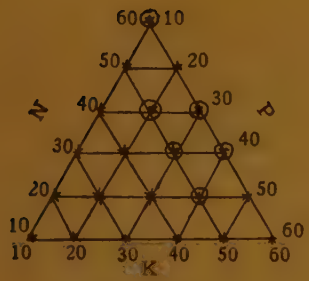
The effect on vegetative growth was therefore not very promising. Increasing P/K ratio on the other hand, when associated with low nitrogen or high nitrogen, did not favour reproductive growth up to any marked extent. Vegetative growth however was highest when the ratio of P/K was 4·0 given along with high nitrogen. The effect

of increasing ratio of N/K on reproductive growth was not as helpful as on vegetative growth. An increasing N/K ratio up to 3·0 was more helpful in development of vegetative organs under high phosphorus feeding. Increasing proportion of nitrogen in comparison to phosphorus when associated with high potash (30 ppm.) provided the ideal condition of nutrition from the point of view of grain yield. Even an N/P ratio of 6: 1 was quite helpful if potash was present in adequate quantity. For reproductive growth a ratio of P/K as 4: 1 or N/K as 3: 1 was relatively more beneficial. Highest yield, therefore, was partially related to supply of these nutrients in the ratios indicated above. Equally vigorous development of plant from the point of view of both vegetative and reproductive growth, therefore, takes place within a narrow range of these ratios. If individual growth characters were taken into account such a specific range was not at all noted. High tillers and leaf size for instance might take place under wide ranges of these ratios (Tables I–VI).

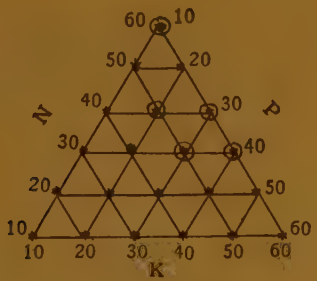
This aspect of the question of nitrogen utilisation to a higher or lower degree appears to be one of the most fundamental points which remain to be elucidated in this plant. Just likely, compositional characteristics of leaves and other tissues might help in throwing further light on the nature of nutritional relation but this is a matter for future investigation.

So far as physiological balance between different salts was concerned, a narrow range of N/P or N/K or P/K ratios may be suggested. But individual development of plant organs did not seem to be in any way specificially controlled by the state of physiological salt balance in the narrow range obtained for grain and straw yield. In this connection mention may be made of the work of Gericke (1929) and Hibbard (1927). These investigators noticed that a wide range of salt proportion was equally satisfactory for early growth and within the limits of concentration used. No correlation was found between the amount of sulphate or phosphate in the solution. None of the cation ratios Ca/Mg, K/Mg, or K/Ca had any significance. In soils Hibbard (1927) pointed out that yield of wheat and other cereals may be identical under somewhat wide variation of nutrient ratios and that plants were so accustomed to extremes of nutrition in different seasons that any specific range was not of much practical importance under field conditions. From the point of view of growth, however, data collected in the present instance, under pot conditions, showed the fundamental nature of certain salt porportions in determining the intensity of vegetative or reproductive growth though evidences also indicated that such a controlling nutritional mechanism does not operate in the development of individual plant organs. How far such a narrow range of physiological balance would be helpful under field conditions cannot be said with any degree of certainty for the present.

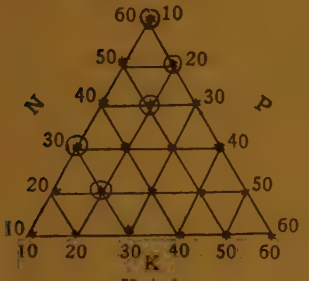
It is also evident from Fig. 5 that treatment number 8 having a nutrient proportion of $N_{40}P_{20}K_{20}$ was having a marked effect on leaf number, tillers, height, dry weight and leaf size. Similarly, treatment number 1 ($N_{20}P_{10}K_{10}$) also appeared to be quite helpful from



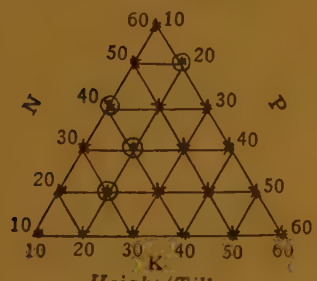
Leaf Number



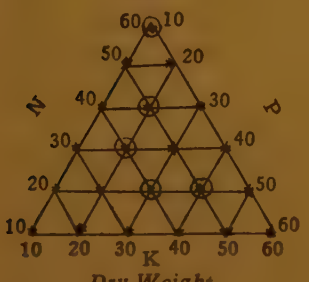
Tiller Number



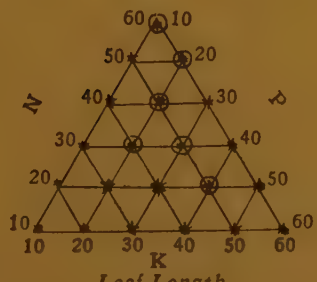
Height



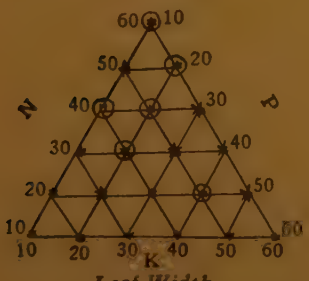
Height/Tiller



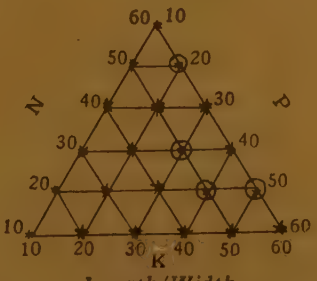
Dry Weight



Leaf Length



Leaf Width



Length/Width

FIG. 5. Effect of various ratios upon growth characters of barley. Circles indicate the position of the best ratios upon various characters.

the point of view of majority of plant characters. From the point of view of dry weight a higher proportion of nitrogen relative to phosphorus and potash appeared more profitable (*e.g.*, in culture containing $N_{60}P_{10}K_{10}$) than more balanced ratio of $N_{40}P_{20}K_{20}$. Other helpful ratios did not seem to exhibit such all-round effects. Their utility under field conditions may therefore be profitably tested.

Occasionally a reciprocal relationship between the nutrients has been suggested. But in the present instance this was not specifically noted at all. There was also no critical range of poverty adjustment or luxury consumption. The barley plant in a way, adapted its nutritional needs markedly with the result that equally vigorous growth took place under extremes of nutritional conditions. This might to a certain extent be possible in view of high efficiency of the plant for utilisation of various elements. Even under low nitrogen conditions adequate supply of phosphorus and potash helped in greater efficiency of nitrogen utilisation with the results that high vegetative activity was recorded under these conditions.

Summary

The paper narrates the effect of 21 ratios of nitrogen, phosphorus and potassium upon growth and developmental characters of barley grown under pot cultures in local soil (sandy loam). Analysis of response has been done in terms of height, tillering, leaf number, leaf size, weight of vegetative and reproductive organs and dry weight of entire plants.

Both age and fertiliser treatments affected growth significantly. The higher the age the greater was the height, leaf number and leaf size while tillering was reduced at later stages. This was true irrespective of the treatments under which the plant grew.

Optimum ratios for different characters varied with plant character and equally useful effects were discernible under wide variations in N–P–K ratios. A change in the ratio of N/P, P/K or N/K affected growth significantly.

Growth of plants did not exhibit any rigid relation with either the total concentration of N–P–K or the relative proportion of N or P or K in the medium. No critical range of poverty adjustment or luxury consumption was noticed. The plant evinced good growth under extremes of conditions showing great nutritional adaptability for good growth.

On reproductive growth, an increasing N/P ratio was found to be favourable while higher P/K ratios were not so promising. On vegetative growth increase in N/K ratio appeared favourable. A N/P, P/K and N/K ratio of 6:1, 4:1 and 3:1 respectively was relatively more helpful than others from point of view of grain yield.

An all-round favourable effect upon growth of barley was noticed under a fertiliser mixture of 40 ppm. N, 20 ppm. P, and 20 ppm. of K. From dry weight point of view a higher proportion of N such as under 60 ppm. N, 10 ppm. P and 10 ppm. of K was more effective.

No reciprocal relation between elements was noticeable. The data have been discussed in relation to the nutrition provided and the nature of physiological balance between different nutrients.

TABLE I

The proportion and ratio of N-P-K in the culture medium

No.	Treatment combination*	Total salt concentration	Percentage salt proportion			N/P	N/K	P/K
			N	P	K			
1	N60 P10 K10	80	75·0	12·5	12·5	6·0	6·0	1·0
2	N50 P10 K20	80	62·5	12·5	25·0	5·0	2·5	0·5
3	N40 P10 K30	80	50·0	12·5	37·5	4·0	1·33	0·33
4	N30 P10 K40	80	37·5	12·5	50·0	3·0	0·75	0·25
5	N20 P10 K50	80	25·0	12·5	62·5	2·0	0·4	0·20
6	N10 P10 K60	80	12·5	12·5	75·0	1·0	0·166	0·166
7	N50 P20 K10	80	62·5	25·0	12·5	2·5	5·0	2·0
8	N40 P20 K20	80	50·0	25·0	25·0	2·0	2·0	1·0
9	N30 P20 K30	80	37·5	25·0	37·5	1·5	1·0	0·66
10	N20 P20 K40	80	25·0	25·0	50·0	1·0	0·5	0·50
11	N10 P20 K50	80	12·5	25·0	62·5	0·5	0·2	0·40
12	N40 P30 K10	80	50·0	37·5	12·5	1·33	4·0	3·0
13	N30 P30 K20	80	37·5	37·5	25·0	1·0	1·5	1·5
14	N20 P30 K30	80	25·0	37·5	37·5	0·66	0·66	1·0
15	N10 P30 K40	80	12·5	37·5	50·0	0·33	0·25	0·75
16	N30 P40 K10	80	37·5	50·0	12·5	0·75	3·0	4·0
17	N20 P40 K20	80	25·0	50·0	25·0	0·5	1·0	2·0
18	N10 P40 K30	80	12·5	50·0	37·5	0·25	0·33	1·33
19	N20 P50 K10	80	25·0	62·5	12·5	0·40	2·0	5·0
20	N10 P50 K20	80	12·5	62·5	25·0	0·20	0·50	2·50
21	N10 P60 K10	80	12·5	75·0	12·5	0·16	1·0	6·0

* Figures at the base indicate dose of N, P and K in p.p.m.

TABLE II

Height of plants in relation to age and treatments

(*a*) *Analysis of variance*

Due to	Degrees of freedom	Sum of squares	Mean sum of squares	Value of F 5%	
				Expected	Observed
Replication ..	2	107·43	53·71	3·07	1·5
Age ..	2	23034·14	11517·07	3·07	323·0*
Treatment ..	20	8037·28	401·86	1·60	11·2*
Age × Treatment	40	4770·19	119·25	1·25	3·3*
Error ..	124	4413·51	35·59	..	..
Total ..	188	40362·55	..	..	..

S.E. per observation = 5·96.

TABLE II—(*Continued*)

(*b*) *Interaction between Age and Treatments*

Treatment No.	Stage I 50 days	Stage II 68 days	Stage III 86 days	Mean of 9
1	21·53	51·40	68·60	47·17
2	29·76	39·53	59·06	42·80
3	24·83	51·30	60·90	45·67
4	29·03	47·30	63·84	47·01
5	25·53	43·30	58·40	42·52
6	25·83	30·06	31·90	29·26
7	23·86	51·70	64·13	46·56
8	25·73	51·70	63·83	47·10
9	29·03	52·96	58·86	46·95
10	28·43	41·56	63·36	44·44
11	18·36	29·63	27·53	25·17
12	32·20	45·50	49·43	42·37
13	34·93	53·10	58·66	48·90
14	32·06	45·20	58·66	45·37
15	33·63	39·83	57·06	43·51
16	36·43	39·13	61·40	45·65
17	31·66	56·66	61·93	49·97
18	31·10	44·33	63·63	46·35
19	31·76	39·86	53·9	41·84
20	24·33	40·46	44·96	30·60
21	26·23	31·66	33·13	30·34
Mean of 63	28·45	44·10	55·40	

Significant difference at 5% for mean of 63 = 1·71; and for mean of 9 = 4·51.

TABLE III

Total number of leaves in relation to age and treatments

(*a*) *Analysis of variance*

Due to	Degrees of freedom	Sum of squares	Mean sum of squares	Value of F 5%	
				Expected	Observed
Replication ..	2	15·84	7·92	3·07	1·09
Age ..	2	1814·51	907·25	3·07	111·07*
Treatments ..	20	1930·01	96·50	1·60	13·3*
Age × Treatment ..	40	691·29	17·28	1·25	2·39*
Error ..	124	896·16	7·22		
Total ..	188	5437·81			

S.E. per observation = 2·68.

TABLE III—(*Continued*)

(*b*) *Interaction between Age and Treatments*

Treatment No.	Stage I 50 days	Stage II 68 days	Stage III 86 days	Mean of 9
1	11·33	20·33	20·33	17·33
2	9·33	11·66	11·66	10·00
3	8·33	16·00	16·66	13·66
4	10·00	14·66	16·66	13·77
5	10·33	21·33	18·33	16·66
6	6·00	9·00	7·33	7·44
7	8·66	16·66	14·00	14·22
8	8·33	15·00	18·66	14·00
9	9·00	15·66	15·00	13·22
10	8·33	11·66	11·33	10·44
11	6·00	7·33	9·66	7·66
12	9·33	24·33	19·33	17·66
13	10·00	20·33	19·66	16·66
14	10·00	18·00	16·33	14·77
15	9·66	12·66	15·00	12·44
16	9·66	14·66	22·33	15·55
17	10·33	22·66	22·33	18·44
18	8·66	14·00	19·00	15·00
19	10·00	13·66	14·66	12·77
20	7·33	11·00	7·66	8·66
21	8·00	11·00	9·00	9·33
Mean of 63	8·90	15·20	15·4	

Significant difference at 5% for mean of 63 = 0·77; and for mean of 9 = 2·01.

TABLE IV

Total number of tillers in relation to age and treatments

(*a*) *Analysis of variance*

Due to	Degrees of freedom	Sum of squares	Mean sum of squares	Value of F 5%	
				Expected	Observed
Replication ..	2	1·86	0·93	3·07	0·16
Age ..	2	43·63	21·81	3·07	38·90*
Treatments ..	20	108·43	5·42	1·60	9·60*
Age × Treatment	40	39·26	0·98	1·25	0·17
Error ..	124	70·14	0·56	..	..
Total ..	188	263·32	..	..	..

S.E. per observation = 0·075.

TABLE IV—(*Continued*)

(*b*) *Interaction between Age and Treatments*

Treatment No.	Stage I 50 days	Stage II 68 days	Stage III 86 days	Mean of 9
1	3·00	5·00	4·33	4·11
2	2·33	2·33	2·66	2·44
3	2·33	3·00	3·00	2·77
4	2·33	3·00	3·00	2·77
5	2·66	4·33	3·30	3·44
6	1·00	2·00	1·66	1·55
7	2·00	3·00	3·00	2·66
8	1·66	3·30	3·66	2·88
9	2·33	3·00	3·00	2·77
10	2·00	2·33	2·00	2·11
11	1·33	1·00	1·33	1·22
12	2·00	5·66	3·66	3·77
13	2·33	4·66	3·66	3·55
14	2·00	3·00	3·30	2·77
15	1·66	2·66	3·00	2·44
16	2·33	3·66	4·33	3·44
17	2·33	5·00	3·66	3·66
18	2·00	3·33	4·00	3·11
19	2·33	3·00	3·00	2·77
20	1·33	1·33	1·66	1·55
21	2·00	2·00	1·66	1·88
Mean of 63	2·07	3·12	2·99	..

Significant difference at 5% for mean of 63 = 0·021; and for mean of 9 = 0·056.

TABLE V

Leaf length as affected by age and treatments

(*a*) *Analysis of variance*

Due to	Degrees of freedom	Sum of squares	Mean sum of squares	Value of F 5%	
				Expected	Observed
Replication ..	2	89·90	44·9	3·07	5·2
Age ..	2	839·80	419·9	3·07	49·4*
Treatments ..	20	2538·43	126·9	1·60	14·9*
Age × Treatment ..	40	746·98	18·7	1·25	2·2
Error ..	124	1061·74	8·5		
Total ..	188	5276·85			

S.E. per observation = 2·9.

TABLE V—(*Continued*)

(*b*) *Interaction between Age and Treatments*

Treatment No.	Stage I 50 days	Stage II 68 days	Stage III 86 days	Mean of 9
1	21·63	22·90	28·93	24·50
2	22·40	24·00	21·63	22·67
3	23·03	31·73	27·86	27·54
4	21·70	28·36	26·23	25·43
5	23·23	25·96	25·43	24·87
6	17·30	19·13	13·86	16·80
7	25·76	27·86	29·26	27·63
8	17·00	30·80	30·72	26·16
9	23·06	31·56	30·23	28·30
10	18·76	28·66	22·93	23·45
11	15·63	20·46	14·86	16·99
12	22·80	29·96	24·03	25·60
13	25·50	31·46	29·20	28·72
14	21·96	27·63	27·76	25·80
15	23·10	27·76	25·93	25·60
16	25·26	27·10	27·40	26·60
17	22·26	30·10	35·03	28·46
18	21·56	26·73	27·13	25·14
19	20·36	24·46	23·53	22·80
20	16·00	16·43	16·46	16·33
21	20·46	20·23	21·46	20·72
Mean of 63	21·37	26·34	25·14	

Significant difference at 5% for mean of 63 = 0·82; and for mean of 9 = 2·18.

TABLE VI

Breadth of leaves as affected by age and treatments

(*a*) *Analysis of Variance*

Due to	Degrees of freedom	Sum of squares	Mean sum of squares	Value of F 5%	
				Expected	Observed
Replication ..	2	0·02	0·01	19·50	0·4
Age ..	2	3·80	1·90	3·07	82·0*
Treatments ..	20	6·73	0·33	1·60	14·0*
Age × Treatments ..	40	6·13	0·15	1·25	6·5*
Error ..	124	2·89	0·02		
Total ..	188	19·57			

S.E. per observation = 0·0048.

TABLE VI—(*Continued*)

(*b*) *Interaction between Age and Treatments*

Treatment No.	Stage I 50 days	Stage II 68 days	Stage III 86 days	Mean of 9
1	1·13	1·41	1·80	1·45
2	1·30	1·23	1·50	1·34
3	1·16	1·50	1·76	1·47
4	1·13	1·53	1·66	1·44
5	1·23	1·43	1·43	1·36
6	1·10	1·00	0·86	0·99
7	1·30	1·73	1·76	1·60
8	1·00	1·60	1·76	1·45
9	1·30	1·80	1·82	1·63
10	1·06	1·40	1·60	1·35
11	0·88	1·06	0·96	0·97
12	1·20	1·63	1·56	1·46
13	1·36	1·73	1·60	1·56
14	1·16	1·56	1·56	1·43
15	1·20	1·36	1·56	1·37
16	1·33	1·00	1·60	1·31
17	1·25	1·63	1·76	1·52
18	1·16	1·36	1·40	1·31
19	1·03	1·26	1·26	1·19
20	0·93	1·26	1·16	1·12
21	1·00	1·06	1·00	1·02
Mean of 63	1·15	1·40	1·49	..

Significant difference at 5% for mean of 63 = 0·0013; and for mean of 9 = 0·035.

TABLE VII

Height/total shoot number, length/breadth of leaves and dry weight of plant in relation to nutrition

Treatment No.	Height/total tillers			Length/ breadth of leaves*	Dry weight†
	50 days	68 days	86 days		
1	5·40	8·56	12·80	16·07	4·43
2	9·00	11·80	16·10	14·42	2·13
3	7·52	12·82	15·22	15·83	3·80
4	9·00	11·82	15·95	15·80	3·56
5	7·00	8·10	13·50	17·70	2·04
6	12·91	10·02	12·00	16·23	0·85
7	7·95	12·92	16·05	16·60	3·01
8	9·60	12·02	13·70	17·40	3·72
9	8·70	13·24	14·71	16·80	4·08
10	9·48	12·40	21·10	14·30	2·42
11	7·90	14·81	11·80	15·30	1·21
12	10·73	6·80	10·60	16·40	3·92
13	10·40	9·30	12·60	18·25	3·46
14	10·69	11·30	13·60	17·86	4·06
15	12·60	10·90	14·26	16·60	2·59
16	10·90	8·40	11·50	16·60	4·23
17	9·50	9·44	13·20	19·42	5·07
18	10·37	10·02	12·72	19·33	4·17
19	9·50	9·96	13·47	18·54	3·19
20	9·10	17·30	16·90	14·10	1·30
21	8·74	10·55	12·40	21·46	1·78

* At 86 days. † At harvest.

TABLE VIII

Correlation coefficient between dry weight at harvest and growth characters at various stages

Characters	50 days	68 days	86 days
Height *vs.* total dry weight ..	0·46 ±0·18	0·71±0·11	0·22±0·074
Average tiller *vs.* total dry weight	0·64 ±0·135	0·74±0·104	0·86±0·059
Average leaf number *vs.* total dry weight	0·69 ±0·12	0·69±0·120	0·87±0·055
Height/total shoot *vs.* total dry weight	−0·034±0·23	−0·42±0·19	−0·24±0·21

Literature Cited

1. Alov, A. 1944. The N/K ratio in the nutrition of cereals at different stages of growth. Proc. Lenin. Acad. Agri. Sci. U.S.S.R. 1944 (1): 31–38.
2. Beckenbach, J. R., Robbins, W. R. and Shive, J. W. 1938. Nutrition studies with corn. II. A statistical interpretation of the relation between the ionic concentration of the culture solutions and the element content o the tissues. Soil Sci. 45 (5): 403–426.
3. Costache, N. 1940. Le beosin en engrais du sol determine par la methode physiologique vegetale. Bull. Inst. Cult et Ferm Tabæ. 29 (1): 20–32.
4. Craig, N. 1939. Resume der Raffort annuel de la station de Recherches Sur la Caune a sure 1939 Section de Chemie. Rev. Agri. Ile. Maurice. 19 (2): 46–48.
5. ————. 1941. Foliar diagnosis. Annual Report of the Sugarcane Research Station for the Year 1940—Chemistry. Rev. Agri. Ile. Maurice. 20 (6): 360.
6. Dutoil, G. B. and Beater, B. E. 1939. A study of plant food absorption. Proc. South African Sugar Techno. Association. 13: 60–63.
7. Gericke, W. F. 1929. Some relations of maintained temperature to germination and early growth of wheat in nutrient solution. Philippine Journ. Sci. 38: 215–240.
8. Hibbard, R. P. 1927. Negative results on physiological balance in soil cultures. Plant Physiology. 2: 1–38.
9. Lal, K. N. and Pathak, H. S. 1948. Effect of fertiliser deficiency and sufficiency upon growth and development of sugarcane. Journ. Ind. Bot. Soc.
10. ——— and Prasad, G. 1948. Growth characteristics and seed quality of wheat as influenced by nitrogen, phosphoric acid and potash. Proc. Nat. Acad. Sci. India.
11. Lundegårdh, H. 1941. Die Tripelanalyse Theoretische und praktischs Grundlagen einer pflanzen physiologischen. Methode zur Bestimmung des Dungerbedurfinisses des Acker bodens. Lantbrukshog-Skolans Annaler. 9: 127–221.
12. Macy, P. 1936. The quantitative mineral nutrient requirement of plants. Plant Physiology. 11 (4): 749–764.
13. McCalla, A. G. and Woodford, E. K. 1938. Effects of a limiting element on the absorption of individual elements and on the anion: cation balance in wheat. Plant Physiology. 13 (4): 695–712.
14. Murneek, A. E. and Gildheaus, E. J. 1931. Leaf diagnosis and the interpretation of fertiliser requirement of plants. Science 74. (1906): 39–41.
15. Murphy, H. F. 1945. Fertilising wheat for yield and quality. Oklahoma Agri. Expt. Sta. Bull. 285: 1–21.
16. Norem, W. Luther. 1936. Mineral nutrition and seasonal growth of *Agarethum* in sand cultures with auto-irrigation. American Journ. Bot. 23 (8): 545–555.
17. Stanford, G., Kelley, J. B. and Pierre, W. H. 1941. Cation balance in corn grown on high lime soils in relation to K deficiency. Soil Sci. Soc. Amer. Proc. 6: 335–341.
18. Singh, B. N., *et al.* 1940. Progress Report of Researches on physiology of wheat and sugarcane. Imperial Council of Agricultural Research. 1938–40.
19. ————. 1941. Age fertiliser effects upon certain aspects of the physiology and chemistry of sugarcane. Proc. Ind. Acad. Sci. B. 13 (5).
20. Thomas Walter and Mack, W. B. 1943. Foliar diagnosis in relation to plant nutrition under different conditions of weather and soil reaction. Soil Sci. 56 (3): 197–212.

21. Thomas Walter and Mack, W. B. 1941. Foliar diagnosis, study of climate influence on the nutrition of spring and fall grown green-house tomatoes. Plant Physiology. 16 (1): 117–144.

22. ————————. 1940. Foliar diagnosis of differentially fertilised green-house potatoes with and without manures. Journ. Agric. Res. 60 (12): 811–832.

23. ————————. 1941 *b*. Foliar diagnosis in relation to soil heterogeneity. Soil Sci. 52 (6): 455–468.

24. ————————. 1940. Salient features of the method of foliar diagnosis. Proc. Amer. Soc. Hort. Sci. 37: 253–260, 1939.

25. ————————. 1933. Absorption, utilisation and recovery of nitrogen. phosphorus and potash by apple trees grown in cylinders and subjected to differential treatment with nutrient salts. Journ. Agric. Res. 47 (8): 565–581.

26. Tyner, E. H. 1947. The relation of crop yields to leaf nitrogen, phosphorus and potash content. Soil Sci. Soc. Amer. Proc. 12: 317–323.

STUDIES IN LAURACEÆ—I. FLORAL ANATOMY OF *CINNAMOMUM INERS* REINW. AND *CASSYTHA FILIFORMIS* LINN.

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The family Lauraceæ, which is mainly tropical in distribution, is taxonomically interesting; it is placed in the Monochlamydeæ by Bentham and Hooker (1862–63) and in Ranales by Engler (1924) and Rendle (1938). Hutchinson (1926) placed it in a separate order Laurales of Archichlamydeæ along with Myristicaceæ and Monimiaceæ. The position given by him is supported by Garrat's (1933, 1934) observations on the wood anatomy of these three families. Hutchinson also thinks that the family is derived from Magnoliales by reduction. Willis (1948) regards this family as a connecting link between Ranales and Thymeleæceæ.

Comparatively little work has been done on the floral anatomy of this family. The floral anatomy of *Persea americana* has been described by Reece (1939) and Saunders (1939) has given a few observations on *Laurus nobilis*. The present paper describes the floral anatomy of *Cinnamomum iners* Reinw. and *Cassytha filiformis* Linn. The material of *Cassytha* was collected locally and that of *Cinnamomum* at the Indian Botanic Gardens, Sibpur. Serial transverse sections of flower buds of various ages fixed in FAA were cut according to customary methods and stained in safranin and fast green.

Cinnamomum iners

The flowers are pedicillate, trimerous and possess six perianth segments arranged in two whorls and united below into a cup. There are four whorls of stamens with three members in each whorl. The two outer are adnate to the perianth segments, while the inner are free. Each member of the third and fourth whorls bears two lateral glandular outgrowths. The fourth whorl is completely staminodal. The anthers of the two outer whorls are introrse while those of the third whorl are extrorse. All anthers are bilocular and show valvular dehiscence. The ovary is monocarpellary, unilocular with a single pendulous ovule and terminates in a solid style.

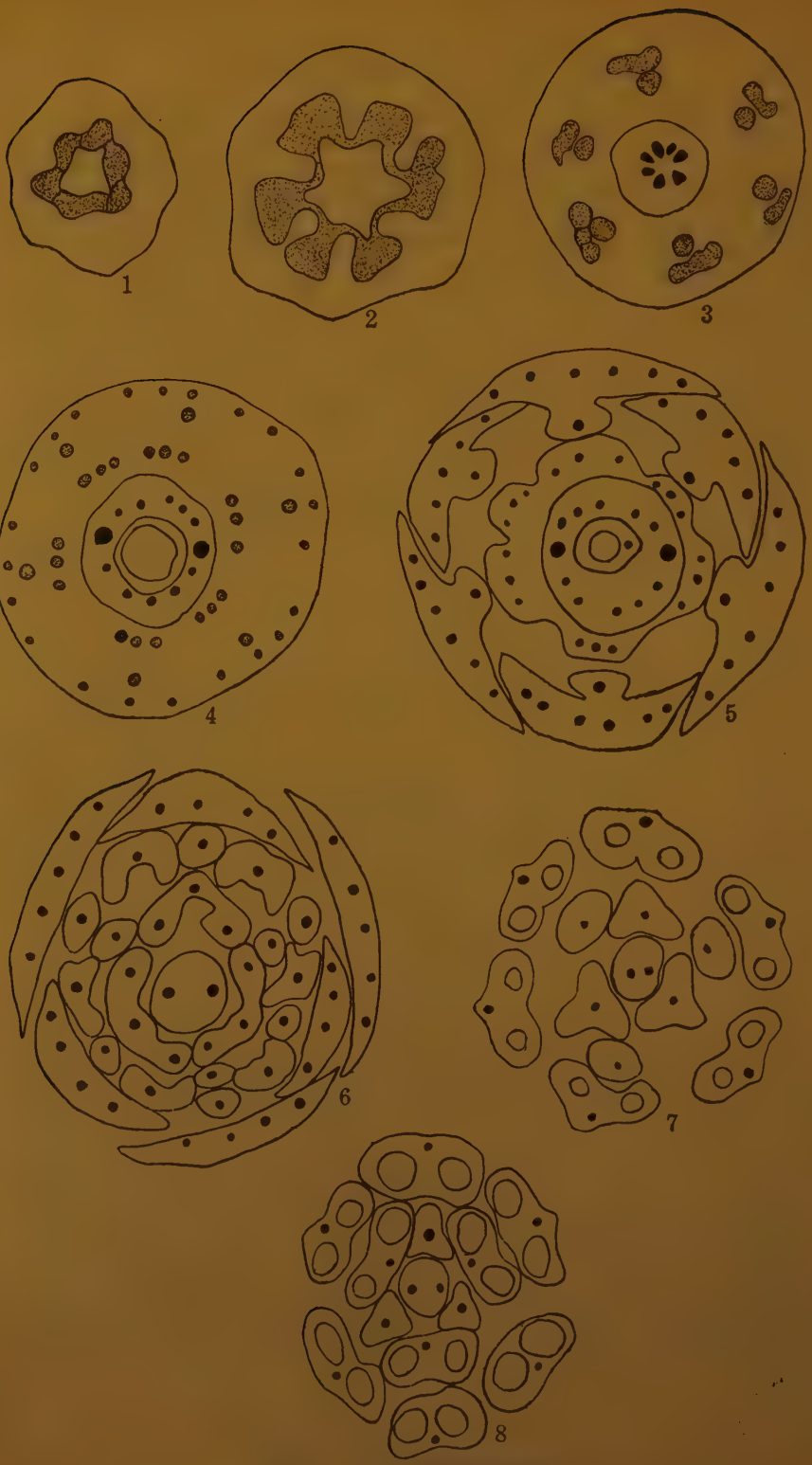
The pedicel shows a closed ring of vascular bundles which undergo secondary thickening to some extent. From this six prominent traces diverge and function as the conjoint (Fig. 1) traces for the perianth and stamens (Fig. 2). The remaining bundles at the centre serve as the vascular supply of the ovary (Fig. 3). The peripheral bundles divide in a tangential manner and form an inner series of bundles which

constitute the supply for the two inner whorls of stamens and an outer series which supply the tepals and the two outer whorls of stamens adnate to them (Fig. 4). Then the six outer bundles again divide tangentially and form the bundles for the two series of stamens to the inside and the midrib bundles of the tepals to the outside. Thus, though the floral organs appear to be arranged in trimerous whorls their traces emerge from the receptacular stele along six radii. At about this level the base of the ovary begins to be demarcated from the perianth cup. The latter shows two zones—the inner annular zone from which the two inner whorls of stamens are derived and the outer from which the perianth parts and the two outer whorls of stamens originate. Now the cup undergoes cleavage in such a manner that three tepals are formed to the outside and three to the inside, alternating with the outer. Each tepal is traversed by several bundles. Each filament which gets separated at a higher level, shows a single staminal bundle. In the annular zone the six bundles which are originally demarcated on the tepal radii undergo radial splitting and give rise to six groups of three bundles each. At the level at which the tepals are completely formed, the inner region also breaks up into the filaments of the six stamens which are somewhat tangentially flattened (Fig. 5). Of the four whorls of stamens, thus, the two outer have one bundle and the two inner have three in each of their filaments. At a higher level each member of the third and fourth whorls gives rise to two lateral glandular outgrowths into each of which one staminal bundle passes (Fig. 6), with the result that higher up the filament shows only one bundle (Fig. 7). The bundles at the base of the ovary undergo radial splitting resulting in an increase in their number (Fig. 5). Of these, two are more prominent and these function as the dorsal and ventral traces. The trace for the single pendulous ovule arises at the top of the loculus from the ventral bundle and passes down the funicle. While the remaining bundles fade out towards the top of the ovary, the dorsal and ventral bundles continue their course into the style (Fig. 7). The dorsal bundle terminates at the base of the stigma and the ventral bundle proceeds a little further. The stigmatic hairs first arise laterally on the side of the dorsal bundle.

Cassytha filiformis

The flowers are almost sessile. They possess bracts and bracteoles and resemble those of *Cinnamomum* except that the fourth whorl of the androecium does not bear glandular outgrowths. The style shows a narrow stylar canal.

The short pedicel has a ring of three prominent vascular bundles. These give off first the traces to the bract and bracteoles. By radial splitting they form six bundles at a higher level (Fig. 9). These in their turn divide again resulting in the formation of six small bundles alternating with six large bundles (Fig. 10). The bundles gradually diverge away from the centre and occupy a peripheral position. At a higher level branches arise from the six smaller bundles (Fig. 11), and form almost a closed ring of vascular bundles which constitute the supply for the ovary (Fig. 12). Later on this splits into the



FIGS. 1–8. *Cinnamomum iners*

Fig. 1. Pedicel with a closed ring of vascular bundles. Fig. 2. Six prominent traces depart from the central stele. Fig. 3. The central ovarian bundles and the peripheral conjoint traces for tepals and stamens. Fig. 4. Dorsal and ventral bundles of the ovary differentiated. The perianth cup with the outer series of bundles for the tepals, next a series of six bundles for the outer two whorls of stamens and the innermost six groups of three bundles each for the inner two whorls of stamens. Fig. 5. Tepals and stamens becoming demarcated. Funicle bundle given off. Fig. 6. The inner two whorls of stamens with lateral glandular outgrowths. Style with the dorsal and ventral bundles. Fig. 7. Filaments of the inner two whorls devoid of their glandular outgrowths at a higher level and containing a single vascular bundle. Fig. 8. Fourth whorl of androecium staminodal. Anthers bilocular. Outer two whorls introrse, third whorl extrorse (× 30).

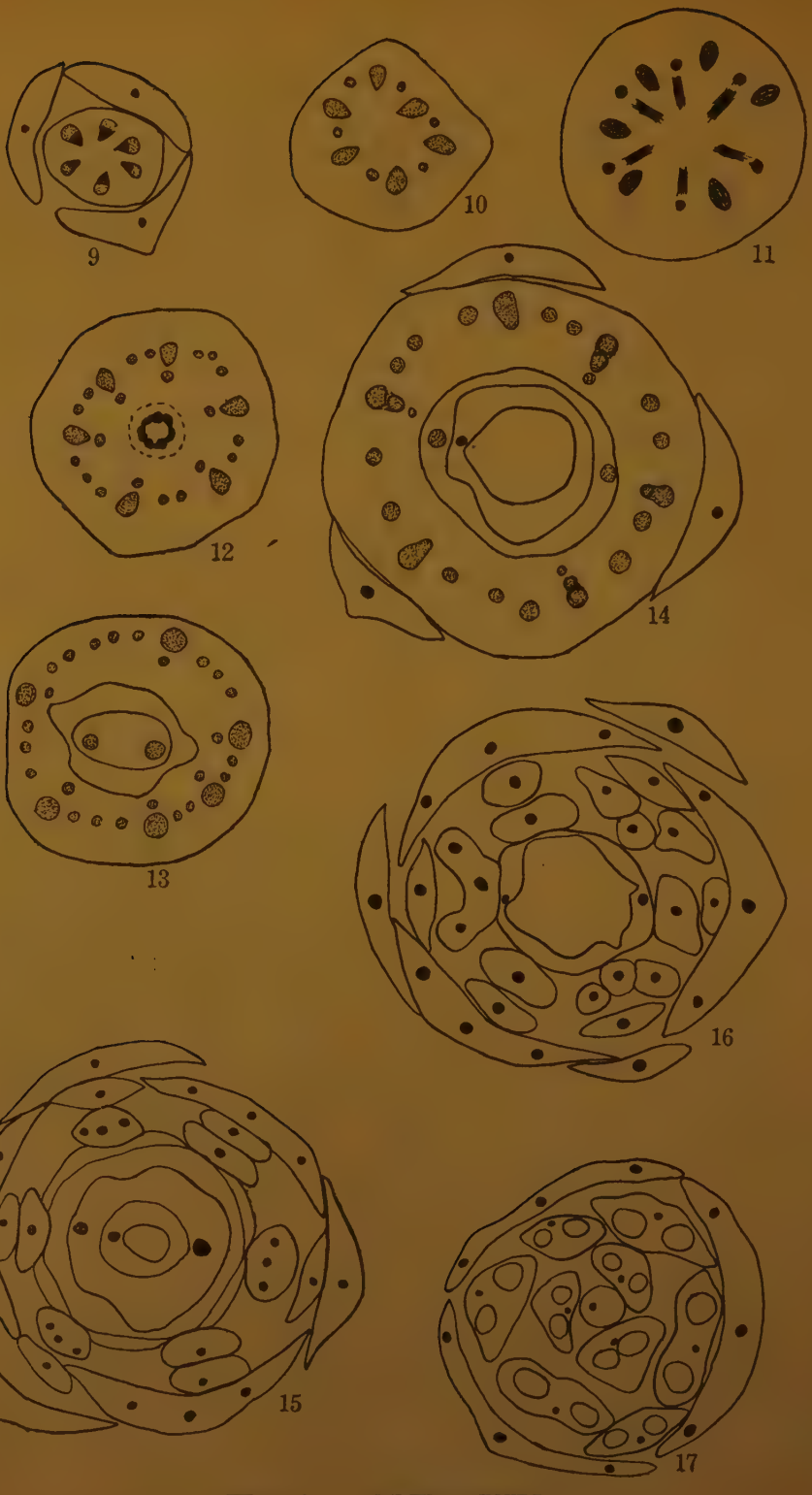
dorsal and ventral bundles (Fig. 13). At the top of the ovary the trace for the pendulous ovule arises from the ventral bundle (Fig. 14). A little above, the dorsal bundle terminates and the ventral bundle continues its course into the style.

After traces supplying the ovary are given off the six smaller bundles at the periphery divide in a radial manner and form laterals of the inner perianth segments (Fig. 12). The larger peripheral bundles function as the conjoint traces for the tepals and stamens. Three of them split tangentially and form the midrib bundle of the outer perianth segments and the traces of the antitepalous stamens. The three outer tepals separate out from the perianth cup. At this level the remaining three bundles split in a similar manner and form the midrib bundles of the inner perianth segments and the bundles of the corresponding antitepalous series of stamens (Fig. 12). After the outer tepals have separated, the traces for the inner perianth and staminal whorls are still included in a broad ring of parenchymatous tissue (Fig. 14). Of these, each staminal bundle of the third whorl divides in a radial manner forming a group of three bundles (Fig. 15). The annular zone splits up into the three perianth segments of the inner whorl and the filaments of the four whorls of stamens. To the inside of each tepal stand two stamens. The bundles of all these are derived from the same conjoint trace. Thus, all the organs are situated on six radii. The inner tepals are larger and are traversed by smaller bundles which consist of a midrib bundle and two laterals.

Of the four whorls of androecium, only the third shows three bundles in each of its filaments. These bear lateral glandular outgrowths (Fig. 16) at the base of the filament into each of which passes a lateral bundle of the filament. The fourth whorl is staminodal. In the rest of the whorls the stamens have bilocular anthers (Fig. 17). As in *Cinnamomum*, the anthers of the outer two whorls are introrse and those of the third whorl are extrorse.

Discussion

There is some difference of opinion among the various authors regarding the nature of the perianth in this family. Hooker (1875) considers it as six-partite and does not make any distinction into sepals and petals. But Rendle (1938) and Saunders (1939) speak of the outer whorl as sepals and the inner as petals. In *Cassytha*, as



FIGS. 9–17. *Cassytha filiformis*

Fig. 9. Pedicel with bract and bracteole. Fig. 10. Stele of pedicel after radial splitting of main bundles. Fig. 11. Ovarian traces being cut off from the smaller bundles. Fig. 12. Receptacle showing vascular supply of ovary at the centre, six larger peripheral bundles split tangentially and the smaller bundles split radially. Fig. 13. Base of ovary showing dorsal and ventral traces ; in the perianth cup the traces for the inner series of stamens and the conjoint traces for the outer series and tepals are seen. Fig. 14. Outer perianth whorl separates from the perianth cup. The remaining traces divide tangentially forming the staminal traces to the inside and the traces to inner whorl of tepals to the outside. Fig. 15. Tepals and antitepalous staminal members demarcated. Filaments of third series of stamens with three bundles each. Fig. 16. Third whorl of stamens with glandular outgrowths and their vascular supply. Fig. 17. Ventral bundle continues in the style. All stamens with bilocular anthers, (× 25).

in *Persea americana* (Reece, 1939), the outer whorl is demarcated earlier than the inner which together with the stamens separates at a higher level. In *Cinnamomum* the perianth cup undergoes cleavage in such a manner as to form both whorls of tepals at the same level. It appears, therefore, that the nature of the perianth in the various genera of this family is variable.

The vascular supply of the various organs of the flower shows evidence of reduction within the family. All the perianth segments of *Cinnamomum* have several bundles each while in *Cassytha* the outer tepals have one bundle and the inner three bundles each.

Saunders (1939) is of the opinion that the stamens in the family are the result of chorosis. Reece (1939) on the other hand, favours the view that they are derived by reduction from an original branch system. The writer is inclined to support the latter view in consideration of the following points. In *Persea americana* the third whorl bears five bundles and the lateral bundles emerge into the glandular outgrowths. The presence of vascular supply in the glandular outgrowths shows that they might be staminodal. In the remaining whorls the stamens show three bundles, but the staminodes are absent. Therefore, the lateral bundles seem to be vestigial in nature and persist even after the complete disappearance of the staminodes. In *Cinnamomum*, two whorls of stamens have staminodal outgrowths as well as their traces while in the other two whorls the staminodes and their vascular supply have disappeared. In *Cassytha* stamens of three whorls are single bundled, while one whorl has staminodal outgrowths and their vascular supply. So *Cassytha* seems to have undergone reduction to a greater extent than the other two genera, the three presenting a series in the reduction of an original branch system.

Even with regard to the ovarian vascular supply *Cassytha* shows greater reduction than *Cinnamomum*, which has besides the dorsal and ventral bundles, several median bundles also. In *Cassytha* there are only two bundles, the dorsal and the ventral. The presence of more than two bundles in *Cinnamomum* suggests that the unilocular ovary is probably derived from a multicarpellary one. Similarly in *Cassytha* the fact that several bundles enter into the formation of the dorsal and ventral bundles indicates the probable derivation of the unilocular ovary from a multicarpellary condition.

The classification of the family into Lauroideæ and Perseoideæ is based mainly on the number of locules in the anther, the former having four and the latter two (Willis, 1948). *Cinnamomum* is placed in Lauroideæ and *Cassytha* in Perseoideæ. Hooker (1875) also described the anthers in the genus *Cinnamomum* as 4-locular (excepting those of the third whorl which are rarely 2-locular) although he expressed the view that the studies in the genus are based on inadequate material. The present study shows that the anthers of all the whorls of stamens in *Cinnamomum iners* are 2-locular like those of *Cassytha*. Thus, the number of locules in the anther does not seem to be an adequate character to provide a basis for classification.

Summary

The vascular anatomy of the flowers of *Cinnamomum iners* and *Cassytha filiformis* has been studied. In *Cinnamomum* the two perianth whorls are cut off at the same level while in *Cassytha* the outer whorl separates earlier. The stamens in *Cinnamomum* have bilocular anthers as in *Cassytha*. The staminal vascular supply shows evidence of reduction from a branch system. The vascular supply of the ovary indicates a probable derivation from a multicarpellary condition.

Acknowledgements

I take this opportunity to express my sincere thanks to Prof. J. Venkateswarlu for suggesting the problem and for his guidance. I am also particularly indebted to Prof. A. C. Joshi and Mr. C. Venkata Rao for their helpful criticism of the manuscript. My thanks are also due to Mr. R. Seshagiri Rao of the Herbarium, Sibpur Botanic Gardens, for the identification of the species of *Cinnamomum*.

Literature Cited

1. Bentham, G. and Hooker, J. D. 1862–83. Genera Plantarum, London.
2. Engler, A. and Gilg, E. 1924. Syllabus der Pflanzenfamilien, Berlin.
*3. Garrat, G. A. 1933. Bearing of the wood anatomy on the relationships of the Myristicaceæ, Trop. Woods. 36: 20–44.
*4. ———. 1934. Systematic anatomy of the woods of the Monimiaceæ, Ibid. 39: 18–43.
5. Hooker, J. D. 1875. Flora of British India, Vol. V, London.
6. Hutchinson, J. 1926. Families of Flowering Plants, I, Dicotyledons, London.
7. Reece, P. C. 1939. Floral Anatomy of Avocado. Amer. Journ. Bot. 26: 429–32.
8. Rendle, A. B. 1938. Classification of Flowering Plants, Vol. II, Dicotyledons, Cambridge.
9. Saunders, E. R. 1939. Floral Morphology, Vol. II, Cambridge.
10. Willis, J. C. 1948. A Dictionary of Flowering Plants and Ferns, Cambridge.

* Original not seen.

ECOLOGICAL AND STATISTICAL NOTES ON THE GRASSES OF KATHIAWAR

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Introduction

The peninsula of Kathiawar which has an area of about 23,600 square miles, lies on the west coast of India between 20° 40′ and 23° 25′ N. latitude and 69° 5′ and 72° 20′ E. longitude. It is bounded on the south and south-west by the Arabian Sea, on the north-west by the Gulf of Cutch and on the east by the Gulf of Cambay. On the north-west it is connected by a narrow neck with the main land of Gujarat. Its extreme length is about 220 miles. Its greatest breadth is about 165 miles. It has a coast line of about 330 miles. From the coast Kathiawar rises to a central tableland where all the rivers take their rise. Except for the alluvial tract, the surface is everywhere undulating, or broken into hills. Its physical features suggest that it may once have been an island or a group of islands of volcanic origin.

Table I

*Meteorological data regarding Kathiawar**

Month	Mean maximum Temperature in °F.	Mean minimum Temperature in °F.	Mean relative humidity per cent. at 8 hrs. I.S.T.	Mean relative humidity per cent. at 17 hrs. I.S.T.	Average monthly Rainfall in inches
January ..	81·26	55·34	57·8	36·5	0·064
February ..	83·54	58·4	62·6	41·25	0·108
March ..	91·84	65·52	66·2	43·0	0·082
April ..	94·14	72·42	70·2	46·75	0·036
May ..	96·54	77·86	76·2	54·25	0·302
June ..	94·18	80·48	78·8	63·75	3·448
July ..	89·08	78·78	83·8	73·25	8·27
August ..	87·0	76·98	85·6	70·75	4·094
September ..	88·5	75·3	83·8	67·25	2·678
October ..	92·72	71·8	73·2	51·5	0·53
November ..	89·42	64·4	59·0	40·75	0·16
December ..	83·46	57·7	56·8	36·5	0·072
Annual ..	89·06	67·26	71·2	51·75	19·844

* This table is based on the data of Dwarka, Jamnagar (North), Rajkot (Central), Veraval and Bhavnagar (Southern), kindly supplied by the Deputy Director-General of Observatories (Climatology and Geophysics). For this I acknowledge my sincere thanks to him and his staff.

The climate is on the whole temperate. January, February and March are marked by heavy dews and thick fogs. The hot season begins in April and lasts until the rains start in June. The monsoon ends in October. The wettest months of the year are July to September. Further details about the climate will be clear from the meteorological data given above.

The present paper deals with certain statistical observations and ecology of the grasses. The data have been obtained by analysing the various publications mentioned under "Literature Cited". The nomenclature followed is that of Blatter and Mc. Cann (1935).

Statistical Synopsis

In all 84 species belonging to 49 genera are recorded from various localities in Kathiawar. Of these 51 species belonging to 43 genera belong to the subfamily *Panicoideæ*, while the remaining 33 distributed among 16 genera belong to the subfamily *Pooideæ*. The ratio of genera to species is 1 : 1·71. The ratio of genera to species of *Panicoideæ* is 1 : 1·545, while that of the *Pooideæ* is 1 : 2·06. The ratio of species of *Pooideæ* to *Panicoideæ* is 1 : 1·545, while the ratio of genera of *Pooideæ* to *Panicoideæ* is 1 : 2·06. Hence the subfamily *Panicoideæ* predominates over *Pooideæ* with regard to both genera and species.

The 84 species belong to 13 tribes. Of these 13 tribes, 8 have one genus. They are *Arundinelleæ*, *Arundineæ*, *Agrosteæ*, *Stipeæ*, *Zoysieæ*, *Sporoboleæ*, *Festuceæ* and *Bambuseæ*. The remaining 5 tribes *Maydeæ*, *Eragrosteæ*, *Chlorideæ*, *Paniceæ* and *Andropogoneæ* are represented by 2, 3, 5, 10 and 21 genera respectively. The tribes having only one species are *Arundineæ*, *Agrosteæ*, *Zoysieæ*, *Festuceæ* and *Bambuseæ*. Tribes having 3 species are *Maydeæ* and *Arundinelleæ*. Tribes having 4 species are *Stipeæ* and *Sporoboleæ*. Tribes *Chlorideæ*, *Eragrosteæ*, *Paniceæ* and *Andropogoneæ* have 7, 10, 20 and 28 species respectively.

Tribes *Andropogoneæ*, *Paniceæ*, *Eragrosreæ* and *Chlorideæ* comprise three-fourths of the number of grass species. Of the 21 genera of *Andropogoneæ*, 15 have one species. Hence there are large number of monotypic tribes and genera.

The interesting feature about these grasses is that the African and Arabo-Persian elements predominate over the Indo-Malayan.

Of the 49 genera, 27 are represented by single species. They are *Coix* Linn., *Sehima* Forsk., *Pollinidium* Stapf., *Apluda* Linn., *Manisuriss* Linn., *Elyonurus* Humb & Bonpl., *Imperata* Cyrill., *Saccharum* Linn., *Sorghum* Pers., *Vetiveria* Thouars., *Arthraxon* Beauv., *Dichanthium* Willemet., *Eremopogon* Stapf., *Andropogon* Linn., *Heteropogon* Pers., *Pseudanthistiria* Hook. f., *Urochloa* Beauv., *Phragmites* Adans., *Heleochloa* Host., *Nazia* Adans., *Halopyrum* Stapf., *Desmostachya* Stapf., *Cynodon* Rich., *Chloris* Swartz., *Dinebra* Jacq., *Aeluropus* Trin., and *Dendrocalamus* Nees.

The following 16 genera have two species each: *Polytoca* R Br., *Ischæmum* Linn., *Chrysopogon* Trin., *Amphilophis* Nash., *Cymbopogon* Spreng, *Iseilema* Hack., *Digitaria* Hall., *Brachiaria* Griseb., *Paspalum* Linn., *Paspalidium* Stapf., *Echinochloa* Beauv., *Panicum* Linn., *Penni-*

setum Pers., *Cenchrus* Linn., *Eleusine* Gaertn., and *Dactyloctenuim* Willd.

The following three genera have three species each: *Themeda* Forsk., *Setaria* Beauv., and *Arundinella* Raddi.

The remaining three genera comprises nearly one-fifth of the total number of species. They are *Eragrostis* Beauv. (8), *Aristida* Linn. (4), *Sporobolus* R.Br. (4). The number of species is shown in brackets.

Of the 84 species 45 are common to Sind, 24 to Cutch and 51 to Gujarat. Of these, the following 17 species occur in all the three areas stated above. They are *Eremopogon foveolatus* Stapf., *Digitaria marginata* Link. var. *fimbriata* Stapf., *Brachiaria ramosa* Stapf., *Paspalidium geminatum* Stapf., *Echinochloa colona* Link., *Setaria verticillata* Beauv., *Pennisetum ciliare* Link., *Cenchrus catharticus* Del., *Phragmites maxima* Bl. & Mc., *Aristida adscensionis* Linn., *A. funiculata* Trin. & Rupr., *Eragrostis ciliaris* Link., *Desmostachya bipinnata* Stapf., *Cynodon dactylon* Pers., *Dactyloctenium ægyptium* Richt. and *Aeluropus repens* Parl.

Sporobolus virginicus Kunth. is peculiar to Kathiawar.

Ecological Features

With the execption of *Dendrocalamus strictus* Nees., all the grasses are herbaceous. They may be either annual or perennial or both. Of the 84 species, 27 are annuals and 42 are perennials. Hence there is a larger number of perennials than that of annuals. Some of the annuals acquire or possess adaptations which induce a perennial habit. Their erect stems becoming decumbent at the base are modified into creeping root stock. Among these are *Eremopogon foveolatus* Stapf., *Andropogon pumilus* Roxb., *Themeda quadrivalvis* O. Kuntze., *Brachiaria isachne* Stapf., and *Brachiaria ramosa* Stapf.

Grasslands are a conspicuous feature of Kathiawar and they may be included under the general ecological type known as savannah. The principal members of the savannah formation are *Ischæmum rugosum* Salisb., *Apluda varia* Hack., var. *aristata* Hack., *Dichanthium annulatum* Stapf., *Eremopogon foveolatus* Stapf., *Cymbopogon martini* Stapf., *Heteropogon contortus* Roem & Schult., *Themeda quadrivalvis* O. Kuntze., etc.

The habitats of these grasses differ. The majority are xerophytic, but species such as *Coix Lachryma-Jobi* Linn., *Polytoca barbata* Stapf., *Ischæmum rugosum* Salisb., *Saccharum spontaneum* Linn., *Vetiveria zizaniodes* Stapf., *Iseilema wightii* Anders., *Brachiaria isachne* Stapf., *Paspalum vaginatum* Sw., *Paspalidium flavidum* A. Camus., *P. geminatum* Stapf., *Echinochloa colona* Link., *E. crus-galli* P. Beauv., *Phragmites maxima* Bl. & Mc., *Panicum antidotale* Retz., *Heleochloa setulosa* Bl. & Mc., *Eragrostis ciliaris* Link., and *Cynodon dactylon* Pers. prefer moist places.

Psammophytes are represented by *Pollinidium binatum* (Retz.) C. E. Hubbard, *Panicum turgidum* Forsk., *Cenchrus biflorus* Roxb., *C. catharticus* Del., *Eragrostis ciliaris* Link., *E. tremula* Hochst., *Chloris barbata* Sw., *Eleusine indica* Gaertn., *E. flagellifera* Nees., and *Dactyloctenium scindicum* Boiss.

Petrophytes are represented by *Manisuris granularis* Linn., *Eremopogon foveolatus* Stapf., *Heteropogon contortus* Roem. & Schult., *Pennisetum ciliare* Link., *Arundinella setosa* Trin., *A. tenella* Nees & Wight, *A. gigantea* Dalz., *Aristida adscensionis* Linn., *A. hystricula* Edgew. and *A. funiculata* Trin. & Rupr.

Halophytes are represented by *Heleochloa setulosa* Bl. & Mc., *Sporobolus indicus* R.Br., *S. verginicus* Kunth., *S. glaucifolius* Hochst., *S. pallidus* Boiss. and *Halopyrum mucronatum* Stapf.

Cymbopogon Schœnenthus Spreng., *C. martini* Stapf. and *Nazia racemosa* Kuntze. are particularly xerophytic.

Saccharum spontaneum Linn. is very variable species. It has three forms: xerophyllous on dry sandy soil, hygrophyllous on swamps and intermediate between xerophyllous and hygrophyllous on loamy soil.

There are some which prefer shade and hence are seen growing underneath big trees, in hedges and amongst bushes. They are *Apluda varia* Hack. var. *aristata* Hack., *Sorghum halepense* Pers., *Dichanthium annulatum* Stapf., *Themeda cymbaria* Hack., *Paspalidium flavidum* A. Camus., *Urochloa setigera* Stapf., *Panicum antidotale* Retz., *Setaria glauca* Beauv., *S. verticillata* Beauv., and *Dinebra retroflexa* Panzer.

These grasses sprout with the first showers of rain from seeds or rhizomes and in a remarkably short time they are well grown. They reach the full luxuriance in the months of October and November. The majority of the species flower at the end of the rains and wither and dry up by January. Flowering period of 60 out of 84 species is known. Of these 3 flower in August, 10 in September, 21 in October, 15 in November, 9 in December, 1 in January and 1 in March. The minimum number of species flower in January, while the maximum flower in October.

Grasses begin to flower in August when the mean temperature is 81·99 F. and mean humidity is 78·175%. With the decrease in temperature and humidity in September, there is increase in the number of flowering grasses. With the increase of temperature and decrease of humidity in October maximum flowering is attained. With the gradual decrease in temperature and humidity in November and December there is gradual decrease in the number of flowering grasses. There is continued increase of temperature from January to June but this does not coincide with the flowering of grasses. June temperature is higher than that of October but this does not affect flowering of the grasses in any way. Hence it can be said that the temperature has nothing to do with the flowering period.

I wish to express my deep sense of gratitude to Dr. A. C. Joshi for his kind interest and help in revising the manuscript.

Literature Cited

Blatter, C. and McCann, C. 1935. The Bombay Grasses, Delhi.

Cooke, T. 1901–08. The Flora of the Presidency of Bombay, London.

Hooker, J. D. 1875–97. The Flora of British India, London.

Kapadia, G. A. 1945. Note on some grasses from Junagadh. Journ. Bom. Nat. Hist. Soc. 45: 259–62.

———. 1947. A Note on Porbandar Grasses. Journ. Guj. Resch. Soc. 9: 122–30.

CONTRIBUTIONS TO THE EMBRYOLOGY OF STERCULIACEÆ

IV. Development of the Gametophytes in *Pterospermum suberifolium* Lam.

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(Received for publication on May 10, 1952)

In a previous contribution (Rao, 1949), the embryology of two species of *Pterospermum* (*P. heyneanum* Wall. and *P. acerifolium* Willd.) was described. As the development of the archesporium in the ovules in this genus was found to be particularly interesting, an intensive study of this phase of development has been undertaken in *P. suberifolium* Lam. Material fixed in formalin-acetic-alcohol was kindly sent by Mr. V. V. Apte from Poona. Customary methods of dehydration and infiltration were followed and Heidenhain's and Delafield's hæmatoxylin were used as stains.

Flowers

Like those of the other species of the genus, the flowers of *Pterospermum suberifolium* also are bisexual, dichlamydeous and pentamerous. The essential organs are raised on a short gynandrophore. There are five groups of fertile stamens of three each alternating with five staminodes. The ovary is 5-carpellary, syncarpous, 5-locular and the midrib of each carpel projects deep into the loculus (Fig. 2). There are numerous ovules in two rows on axile placentæ (Fig. 1). The style is terminal and shows a well marked stylar canal.

Ovules

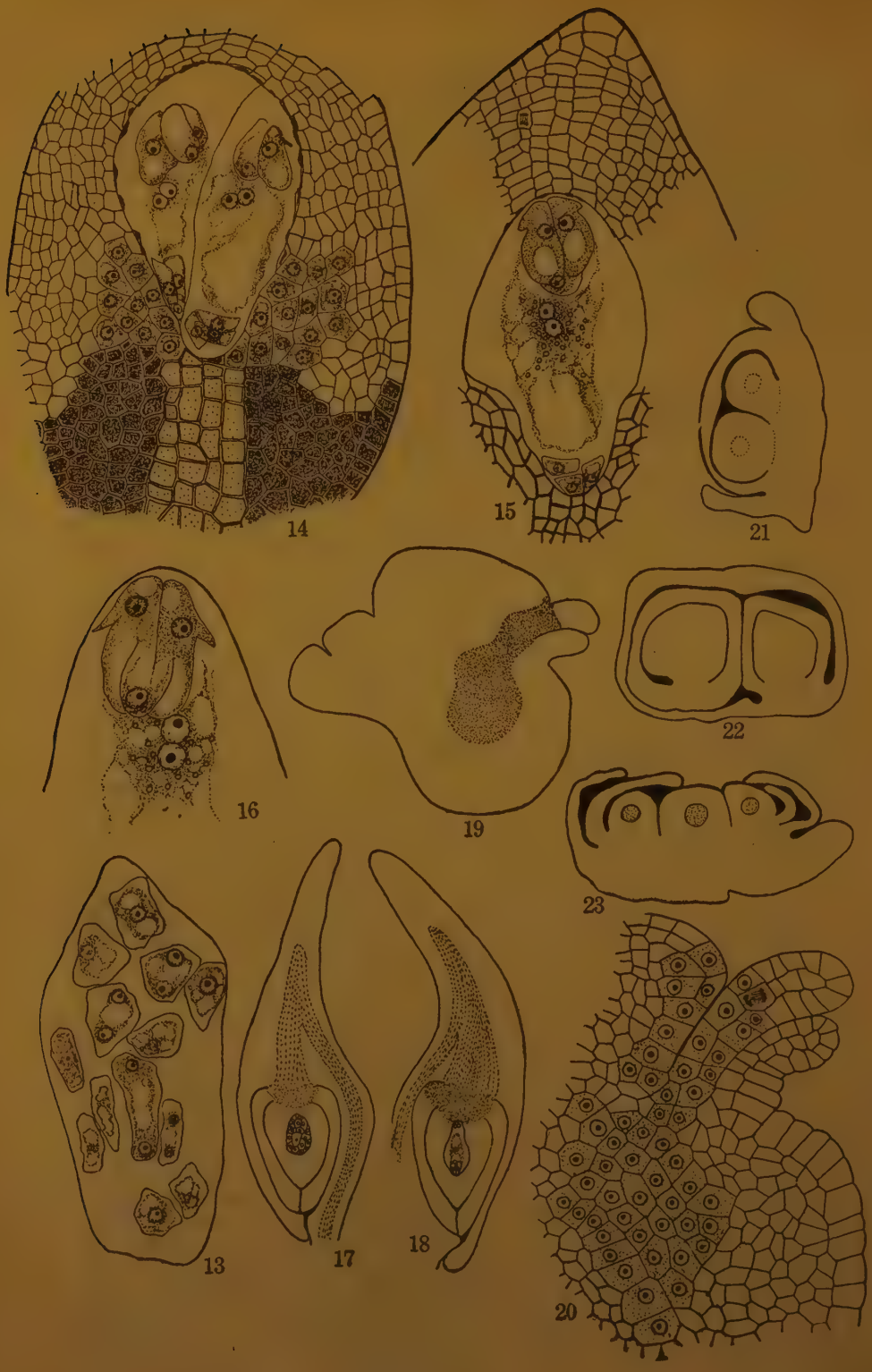
The ovules arise as hemispherical swellings on the placenta and by the time the integument primordia get demarcated, the terminal portion of the ovule begins to curve (Fig. 6). In normal course of development, they rotate completely and become anatropous (Fig. 12). However, as will be described later, this does not always happen. The ovules are bitegmic and crassinucellate. The outer integument which is 3-layered, grows faster than the inner. The cells of its outer epidermis lose their cytoplasmic contents and accumulate some deep staining material, probably tannin. The micropyle, which is formed by both the integuments, has the zig-zag form characteristic of the Malvales (Figs. 17 and 18). Very early in the development of the ovule, *i.e.*, by about the time of demarcation of the integument primordia, the cells of the nucellar epidermis begin to divide periclinally (Figs. 5 and 6). As the archesporial cells function directly without cutting off the primary parietal cells, practically the whole of the nucellus above and to the sides of the sporogenous sphere

FIGS. 1–12

Fig. 1. L.s. ovary showing ovule primordia, × 35. Fig. 2. T.s. of a loculus of ovary, × 35. Fig. 3. Young ovule primordia showing primary archesporium, × 165. Figs. 4 and 5. L.s. ovule primordia showing mitotic divisions in archesporial cells, × 425. Fig. 6. Ovule primordium with integument initials; note periclinal division in nucellar epidermis, × 425. Fig. 7. Young ovule with mass of sporogenous cells and epidermal cap; note the development of wing on chalaza, × 165. Fig. 8. Nucellus of a full grown ovule with mass of sporogenous cells, × 285. Fig. 9. Sporogenous tissue consisting of enlarging functional megaspores, degenerating cells and megaspore-mother cells, × 425. Fig. 10. A few sporogenous cells showing meiotic divisions, × 500. Fig. 11. A linear tetrad of megaspores surrounded by sporogenous cells, × 425. Fig. 12. L.s. loculus of mature ovary showing disposition of ovules, × 30.

consists of the massive 12–16 layered epidermal cap, which has normally a conical outline (Fig. 8). A wing also develops on the chalaza early and measures 1½–2 times the length of the body of the ovule in the full grown condition (Figs. 7 and 11). The cells of the chalaza below the sporogenous sphere stain deeply due to the presence of tannin. The nucellus cells below the antipodal end of the embryo-sac become thick-walled and as they stand more or less in regular rows and extend to the vascular bundle in the chalaza, they form a hypostase-like strand which facilitates the transport of food materials into the embryo-sac (Fig. 14). In the later stages, after all the sporogenous cells get crushed, the cells at the sides of the embryo-sac also become thick-walled (Fig. 15). The ovule attains the maximum size even by the time the megaspore mother cells are full grown and usually ovules with megaspore-mother cells and fully formed 8-nucleate embryo-sacs occur within the same loculus.

All the ovules in a loculus do not develop normally. The loculus itself is small in size and the projection of the midrib into the loculus and the development of the wings on the seeds, bring in problems of space. Developing ovules press hard against the ovary wall or secondary septum and also exert mutual pressure, due to which they become malformed or distorted. Some of the ovules do not find space for rotation and consequently remain orthotropous (Figs. 26 and 27) or hemianatropous (Fig. 24). In some cases, the upper ovule is seen to press upon the lower and prevent the normal development of the wing (Fig. 33). Sometimes the wing of an ovule, instead of growing past the upper ovule, gets beneath its developing outer integument and lifts it up with growth (Figs. 31 and 32). In Fig. 29 is shown a case in which, while one ovule rotated normally and has its micropyle facing the base of the loculus, another twisted in the reverse manner in order to adjust to the available space and has its micropyle facing the top of the loculus. In a large number of cases, the integuments fail to cover up completely and the nucellus is directly exposed (Figs. 24, 30 and 34). Sometimes the outer integument fails to close up and the micropyle is formed only by the inner integument (Fig. 28). According to their growth which is determined by the available space, the nucellus and the integuments have fewer or greater number of cell layers than the usual. The nucellus also may have a semicircular instead of the normal conical outline (Fig. 24). In one case it was noticed that the upper ovule which had enough space, developed the integuments and sporogenous cells normally but the lower one which



FIGS. 13–23

Fig. 13. Several embryo-sacs developing inside the space formed by degeneration of sporogenous cells, × 285. Fig. 14. L.s. ovule showing two 8-nucleate embryo-sacs, mass of sporogenous cells that have not yet degenerated, the zone of tannin-bearing cells and the hypostase, × 425. Fig. 15. A mature ovule with embryo-sac ; the lower half of the sac is invested by thick-walled cells, × 285. Fig. 16. Upper half of embryo-sac with egg apparatus and polar nuclei, × 355. Figs. 17 and 18. Full grown ovules with sporogenous cells and embryo-sac respectively, × 45. Fig. 19. Abnormal ovule with sporogenous cells developed from nucellar epidermis and integument, × 135. Fig. 20. Part of the same magnified, × 285. Fig. 21. T.s. ovule with double nucelli with common integuments, × 45. Fig. 22. T.s. ovule with two nucelli with common outer and separate inner integuments, × 45. Fig. 23. T.s. ovule with 3 nucelli ; the median nucellus has no integuments, × 35.

is hardpressed for space, showed only one integument and scanty nucellus. The cells of the nucellar epidermis in this case, did not undergo periclinal divisions but became radially elongated and showed prominent nuclei and vacuolated cytoplasm resembling the sporogenous cells found below (Figs. 25 and 36).

In addition to the above abnormalities which are caused by the exigencies of space, some ovules were seen with structural abnormalities. Frequently ovules showed double nucelli, either with common outer but separate inner integuments (Fig. 22) or with common outer and inner integuments (Fig. 21). In one case, an ovule was seen with three nucelli (Fig. 23). Only the lateral nucellar primordia developed the integuments while the median one remained naked. In all these cases, the archesporium was developed in the usual manner.

Megasporogenesis and Embryo-sac

The two species of *Pterospermum* previously investigated, showed multicellular archesporium, but it was not possible to ascertain in them whether the numerous functional cells were of primary or secondary origin. This aspect was studied closely in *P. suberifolium*.

As in other species of the genus, in this also the archesporium is multicellular. From the earliest stages when the ovule primordium could be recognised by the uneven contour of the epidermis on the placenta, the group of cells below the epidermis could be identified as archesporial cells. They are characterised by large size, deep staining cytoplasm and prominent nuclei (Fig. 3). This group is subtended by a zone of small meristematic cells which by their active divisions contribute to the growth of the ovule primordium (Figs. 3–6). The epidermal cells which are small at first, enlarge and become somewhat radially elongated till the integument primordia get demarcated and till then undergo only anticlinal divisions. Afterwards, they undergo periclinal divisions and form the epidermal cap.

The archesporial cells enlarge and their cytoplasm becomes vacuolated (Fig. 5), as in typical sporogenous cells. They undergo repeated mitotic divisions in order to increase the number of sporogenous cells (Figs. 4 and 5) and members of the last cell generation function directly as megaspore-mother cells. Ultimately, the mass of sporogenous cells has an ovoid form in the normally developed ovules (Figs. 8 and 9) or a spherical form in the distorted ovules

FIGS. 24–36

Fig. 24. L.s. a hemianatropous ovule with poorly developed nucellus and integuments, × 180. Fig. 25. Part of the same magnified, × 425. Fig. 26. A group of orthotropous ovules, × 45. Fig. 27. One of these magnified ; note shape of nucellus and sporogenous sphere, × 165. Fig. 28. L.s. mature ovule showing aggressive penetration of chalaza by enlarging embryo-sacs ; note micropyle formed only by inner integument, × 90. Fig. 29. A group of ovules with dissimilar orientation, × 30. Fig. 30. A distorted ovule, × 30. Figs. 31 and 32. Ovules which have lifted up the integuments of the upper ovules, × 30. Fig. 33. Wing formation is suppressed by pressure from upper ovule, × 30. Fig. 34. A distorted ovule, × 30. Fig. 35. Two closely placed ovules of which the lower is malformed, × 165. Fig. 36. Part of the lower ovule magnified, × 355.

(Figs. 24, 25 and 27) and measures 60–70 μ in diameter. Counts of the cells from different ovules have shown that they range from 80–100 in number. The number is much larger than in the two species previously studied (Rao, 1949). Cases of such secondary increase of sporogenous cells are rare among angiosperms and are known with certainty only in plants like *Casuarina* (Swamy, 1948) and other amentiferæ.

Though normally the archesporium is confined to the nucellus proper, one abnormal case was observed in which the cells of the inner integument on one side, enlarged considerably and assumed characters of sporogenous cells (Figs. 19 and 20). Some cells of the nucellar epidermis also, instead of undergoing periclinal divisions like the rest, have enlarged. Such supernumerary archesporial cells are reported in a few plants like *Solanum melongena* (Bhaduri, 1932) and *Limnanthes douglassi* (Fagerlind, 1939).

After the ovule has attained the full size, the megaspore-mother cells begin to undergo the two meiotic divisions. Due to being closely packed, the cells show diversity in size, shape and orientation. Usually the cells in the upper region are cubical or tangentially flattened, while those lower down are more elongated (Fig. 9). Due to spatial relations the spindles in the meiotic divisions are oriented differently (Fig. 10) and it is very difficult to place the four megaspores of a tetrad except where they stand in strict linear disposition (Fig. 11). Soon after the completion of the meiotic divisions in a few megaspore-mother cells, there is a rapid enlargement of the functional megaspores of a number of tetrads and degeneration of the non-functional cells. Non-functional megaspore-mother cells persist for some more time and can be seen in various stages like synizesis or diakinesis, surrounding the enlarging embryo-sacs (Fig. 14). Very soon all the functionless cells get crushed out and disappear. In the large space thus formed, 10 or more embryo-sacs could be seen enlarging initially (Fig. 13).

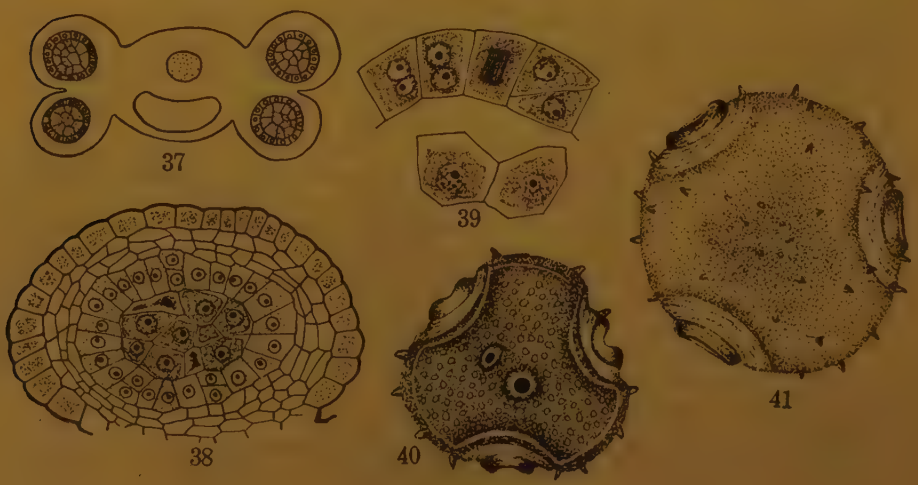
As in meiotic divisions, in the three free nuclear divisions leading to the formation of the embryo-sac also, there is disparity in matter of time. Hence 4-nucleate, 2-nucleate and 1-nucleate embryo-sacs could be seen together in the same ovule. Usually the more precocious and more favourably placed sacs develop further, crushing the rest. It is usual to find 2 or 3 completely formed 8-nucleate embryo-sacs in one ovule (Fig. 14). In one case, however, 34 nuclei were counted in one mature ovule which means that at least 5 embryo-sacs were

developing. Usually the embryo-sacs extend to the zone of tannin-bearing cells in the chalaza (Fig. 15) but occasionally, probably due to the extreme competition among the numerous enlarging embryo-sacs, the chalazal region is penetrated in an aggressive manner (Fig. 28).

The fully developed embryo-sac shows normal features. The sac has a broad micropylar end and a relatively narrow antipodal region which is invested by a sheath of thick-walled cells (Fig. 15). The cells of the egg apparatus are equal in size. The synergids are prominently hooked (Fig. 16) and show 2 terminal vacuoles. The 2 polar nuclei do not fuse till the time of fertilisation and remain pressed together in the vicinity of the egg. They are surrounded by dense cytoplasm which shows starch grains. The antipodals are 3 in number and persist till the time of fertilisation. In one case, there were 3 nuclei in place of polar nuclei and in another, 6 partly fusing nuclei at the middle of the sac. Probably the extra nuclei represent those which have strayed out from the other sacs, after the break-down of the membranes of embryo-sacs.

Microsporogenesis and Male Gametophyte

The anthers are 4-locular and show a broad connective which is prolonged into a hood. By the side of the vascular bundle in the connective is found a mucilage sac (Fig. 37). The wall of the full grown anther is 5–6 cells thick. Cells of the epidermal layer show deep staining contents which diminish with age. The hypodermal layer develops into the fibrous endothecium. The innermost wall layer



Figs. 37–41

Fig. 37. T.s. anther ; note mucilage canal below vascular bundle, × 75. Fig. 38. T.s. anther loculus showing organisation of tapetum and degenerating microspore-mother cells, × 285. Fig. 39. Tapetal cells and microspore-mother cells in prophase I, × 425. Fig. 40. Sectional view of a 2-nucleate pollen grain (shrunken), × 500. Fig. 41. Surface view of a pollen grain, × 500.

develops into the tapetum which is of the secretory type. The biseriate condition of the tapetum at some places (Fig. 39) seems to be associated with the large number of microspore-mother cells in a loculus: 8–12 cells are seen in t.s. and more than 150 in a row in l.s. of anther loculus. As in other species of the genus, degeneration of microspore-mother cells occurs in the metabolic condition (Fig. 38). Microspore tetrads are tetrahedral and cytokinesis takes place by furrowing. The tetrad is invested in the young condition by a special wall of callose.

Pollen grains are shed in the 2-nucleate condition (Fig. 40). In external features, they resemble those of the other species of the genus (Rao, 1950 *a*). The exine is spinescent and shows three germ pores with collar-like rim and a circular harmomegathus around each (Fig. 41). They measure about 50 μ in diameter.

Discussion

The genus *Pterospermum* is interesting in showing multicellular archesporium in the ovules. It could be definitely ascertained in *P. suberifolium*, that there is a secondary increase in sporogenous tissue. Studies in floral anatomy (Rao, 1952) have shown that Sterculiaceæ is the most primitive among the Malvales. Within Sterculiaceæ, there is reduction in floral structure. In the tribe Dombeyeæ in which *Pterospermum* is placed, the flowers are pentacyclic and there is the presence of gynandrophore, numerous stamens and numerous ovules. In the tribe Hermannieæ to which *Melochia* and *Waltheria* belong, the flowers are tetracyclic and there is reduction in the number of stamens, carpels and ovules, and tendency towards perigyny. Associated with these taxonomic characters, we find evidence of primitiveness in the embryological characters of the Dombeyeæ in the presence of multicellular archesporium and the development of 2 or 3 embryo-sacs in one ovule. In *Pterospermum*, the connective of the stamen is prolonged beyond the anthers and this is also looked upon as a primitive feature (Parkin, 1951). In Hermannieæ the archesporium consists of only one functional cell (Rao, 1949 and 1950 *b*).

Multicellular archesporium with secondary increase in the number of sporogenous cells as occurs in *Pterospermum suberifolium* seems to be the most primitive condition in angiosperms, from which other types of archesporium could be derived by reduction. The first stage in reduction is the suppression of mitotic divisions in all but the hypodermal sporogenous cells. The cells cut off by them function as the primary parietal cells which by division add to the nucellus as in *P. heyneanum* (Rao, 1949). That the parietal tissue is potentially sporogenous is evident from the development of some of these cells into sporogenous cells as in Malvaceæ (Stenar, 1925). The next stage is seen in archesporium which is multicellular in origin, out of which only one cell functions while the rest merge into the nucellus. From this can be derived the condition in which there is a single archesporial cell from the beginning. The tendency for cutting off of the perietal cell seems to be reminiscent of the original mitotic divisions which occurred in connection with the secondary increase in sporogenous tissue. Ultimately we get the highest condition in the

Sympetalæ in which the ovules are tenuinucellate and the single archesporial cell functions directly as the megaspore-mother cell without cutting off any primary parietal cell.

Summary

The development and structure of the ovule, male and female gametophytes of *Pterospermum suberifolium* Lam., were studied.

Normally, the ovules are bitegmic, anatropous and crassinucellate, with a zig-zag micropyle formed by both the integuments. But for want of space within loculus, several ovules become malformed. Ovules with double and triple nucelli are also met with.

The archesporium is multicellular in origin. A further increase in the number of sporogenous cells is brought about by repeated mitotic divisions of these cells. The sporogenous cells function directly as the megaspore-mother cells, and the nucellar epidermis by periclinal divisions forms a massive epidermal cap. There are about 100 sporogenous cells in an ovule. Some of these cells undergo meiotic divisions and the rest degenerate and get crushed by the large number of developing embryo-sacs.

Embryo-sac development occurs according to the normal type. Double and triple 8-nucleate embryo-sacs were seen in an ovule.

The wall of the mature anther is 5-layered of which the hypodermal layer develops into the fibrous endothecium and the innermost into the tapetum which is of the secretory type. Some of the microspore-mother cells degenerate early. The pollen grains are shed in the 2-nucleate stage. They are 3-porate and spinescent.

Acknowledgements

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Literature Cited

Bhaduri, P. N. 1932. The development of ovule and embryo-sac in *Solanum melongena* L. Jour. Ind. Bot. Soc. 11: 202-24.

Fagerlind, F. 1939. Kritische und revidierende Untersuchungen über das Vorkommen des Adoxa ("Lilium")-Typus. Acta Horti. Bergiani. 13: 1-49.

Parkin, J. 1951. The protrusion of the connective beyond the anther and its bearing on the evolution of the stamen. Phytomorphology. 1: 1-8.

Rao, C. V. 1949. Contributions to the embryology of Sterculiaceæ—I. Jour. Ind. Bot. Soc. 28: 180-97.

———. 1950*a*. Pollen grains of Sterculiaceæ. Ibid. 29: 130-37.

———. 1950*b*. Contributions to the embryology of Sterculiaceæ—II. *Waltheria indica* L. Ibid. 29: 163-76.

———. 1951. Contributions to the embryology of Sterculiaceæ—III. *Melochia corchorifolia* L. Ibid. 30: 122-31.

———. 1952. Floral anatomy of some Malvales and its bearing on the affinities of the families included in the order. Ibid. 31: 171-203.

Stenar, H. 1925. Embryologische studien. I. Zur embryologie der Columniferen. Diss. Uppsala.

Swamy, B. G. L. 1948. A contribution to the life-history of *Casuarina*. Proc. Amer. Acad. Arts and Sci. 77: 1-32.

THE VEGETATION OF THE TERRACES OF THE TONS RIVER, NEAR TAPKESHWAR, DEHRA DUN

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It was shown in a recent study (Puri, 1950) of the forest communities of the Dun Valley that good quality sal forests occur on deep soils formed by the Siwalik clay. On conglomerates which produce shallow, stony soils, the growth of sal was poor and stunted, and the community was mixed with a large number of miscellaneous species. The pH of the sal-bearing soils in the area was usually low, whereas soils of high pH value either supported miscellaneous forest communities without sal or early riverain communities. Low pH values were also recorded in impoverished shallow soils bearing *Zizyphus jujuba* community. With a view to see if similar factors govern the growth of sal community in other areas as well, the vegetation on the terraces of river Tons, near Dehra Dun, was studied in the months of April–May 1950, under the supervision of Dr. G. S. Puri, to whom I am grateful for constant guidance.

Tons is a small tributary of the Asan river flowing in NE–SW direction in the central part of the Dun Valley. It rises from the outer ridges of the Himalayas, below Mussoorie, and passes through limestone rocks, bringing large amounts of calcium carbonate that form extensive deposits of calcareous tuffa along its banks at lower levels. These calcareous deposits are conspicuous near Dehra Dun cantonment. Here four terraces of the river are recognisable. The temple of Tapkeshwar is carved out into one such tuffaceous mound on the fourth terrace on the right-hand side of the river. The subsoil water percolates through the calcareous matrix of the mound and trickles down in small drops inside the cave and the name Tapkeshwar is, perhaps, derived from this trickling of the water drops. The river near Tapkeshwar at present cuts through its fourth terrace (Photo 1) and flows through steep gorges of calcareous conglomeratic rock, which are often lying detached and torn (Photo 3). Along the left side of the river, below the temple, where a small tributary meets the Tons, the calcareous matrix of the terrace has been washed away and the underlying boulder conglomerate rock now outcrops on the surface. The bed of the river here widens a bit and forms small islands of new riverain soils on which grasses are present. In the area studied in addition to various terraces there are freshly laid soils of river gravels, sands, etc., which are at places lying on older boulder conglomerate and calcareous tuffa.

The climatic condition in this part of the valley may be represented by the data given in Table I, taken from the New Forest Meteorological

TABLE I

Rainfall and Temperature at New Forest

(Average for ten years, 1941–50)

Month	Rainfall	Mean maximum Temperature °F.	Mean minimum Temperature °F.
January ..	2·75″	66·90	41·15
February ..	2·46″	70·00	43·68
March ..	1·76″	78·80	50·33
April ..	1·19″	90·60	59·25
May ..	1·64″	98·65	66·55
June ..	5·61″	96·85	71·55
July ..	26·59″	88·30	72·65
August ..	27·20″	84·55	71·75
September ..	13·44″	84·80	68·30
October ..	2·49″	82·30	56·88
November ..	0·13″	75·10	46·20
December ..	0·62″	68·95	41·63
Total ..	85·88″		

Observatory, which is at a distance of only a mile from the area studied.

In the months of April–May when the studies were made the climatic conditions were very dry, there being almost no rainfall during this year and temperatures were high. As seen in Table I, the maximum rainfall occurs in the months of July–August and the highest temperatures were recorded in the months of May and June.

The various types of soils mentioned in an earlier paragraph are covered with vegetation, types of which were studied along a transect running S → N from the Mango Orchard, on the north of Kohlagarh village and passing through terraces 1–4 on the right of the river bed and the fourth terrace nearest to the river, on the left, as shown in Fig. 1. Terraces 1–3 are abandoned cultivation lands and bear a bio-edaphic community of *Zizyphus jujuba*. The soil here is characterised by the presence, on the surface, of a large number of rounded stones and loose, coarse river gravels. The subsoil was composed of coarse gravel and sand. The amount of stones and gravels decreased from terraces, 3–1, away from the river bed. The boundaries of the terraces were marked by sharp slopes where soils were usually less stony. Here another bio-edaphic community of *Carissa-Sapium* was found. The associates of *Carissa* were usually *Duranta*, *Vitex* and *Ficus cunia*. These shrubs are commonly badly lopped. On the northern aspect of the fourth terrace the soil was very stony and had large blocks of stones cemented in a conglomerate. On this shallow soil there were shrubs of *Adhatoda vasica*, *Woodfordia fruticosa*, *Murrya koenigii*, *Colebrookia oppositifolia*, etc. These shrubs extended almost to the bank of the river. The fresh river sand was being colonised by grasses. On this terrace there were numerous *pteridophytes*, e.g.,

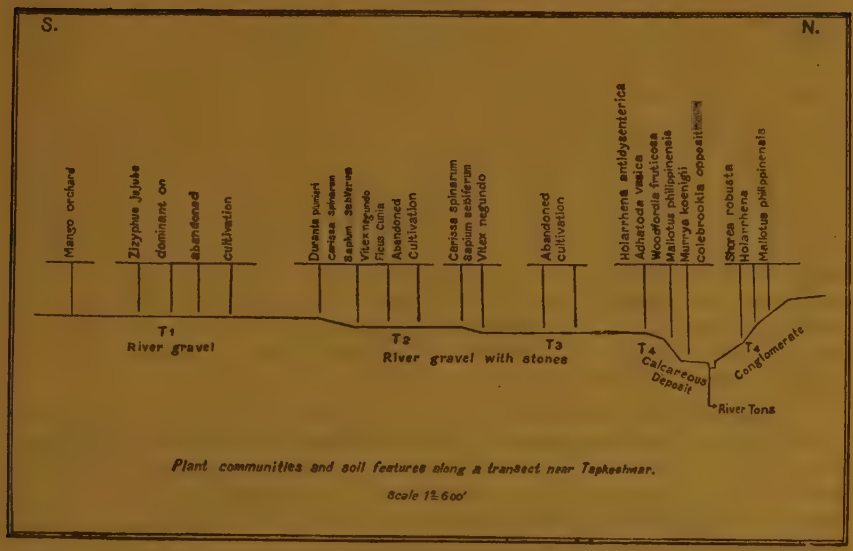

FIG. 1

Selaginella chrysocaulos, *Pteris longifolia*, *Dryopteris prolifera*, *Cheilanthus farinosa* (silver fern) and *Adiantum philippense*, and liverworts like *Marchantia polymorpha*. On the southern aspect loose, bouldary soil supported an open community of Sal—*Mallotus*. Sal poles were malformed and seem to have been badly cut and lopped in the past. The other common species in this community was *Hollarrhena antidysenterica*. It may be stated that the entire area was open to cattle and other disturbances from human population and such poor condition of the vegetation may be partly due to the unhealthy biotic factor.

Detailed analysis of the soils collected from the three plant communities are given in the Appendix. From the pH data given in Table II it seems that malformed and poor stunted Sal—*Mallotus* community occurs mostly in soil whose pH value lies between 5·6–6·5. The other two communities also occur on acidic soils but their greater occurrence was on soils with pH value below 6·0.

On the terraces 1–3 pH of the soils was usually below 6·0, excepting in soil profile 1 under Mango orchards where a value of pH 7·1 was recorded on the surface. The pH in lower layers, especially at the depth of 36″ in most of the pits studied on terraces 1–3, was lower than in 0″ top layer of the soil. In the soils under Sal—*Mallotus* community however, surface soils in some cases (*e.g.*, profiles 7, 8) had lower pH value than in 36″ layer of the soils.

Exchangeable calcium in soils under *Zizyphus* and *Carissa-Sapium* community were usually lower than in the soils in the Sal–*Mallotus*

community. It may be noted that soils with vegetation contained higher percentage of calcium than those without any plant growth. Upper layers of the soil under the sal community contained higher amounts of calcium than the lower layers in almost all pits. In the *Zizyphus* community, however, low quantities of calcium were found in upper layers of the soils. This may be due to calcium having been leached from the upper layers of the soils on the terraces 1–3. These terraces are most probably older and are situated far above the flood-level of the river. Sal–*Mallotus* region being within the flood level of the river, has higher amounts of calcium. Another reason for the high amounts of calcium in surface layers of the sal community may be due to the presence of leaf litter and organic matter. The difference in calcium content of these soils may also be due to different demands of this mineral by the vegetation and as it will be seen, foliar calcium in *Zizyphus* is higher than in either Sal or *Mallotus* studied from this area.

Similarly, the amounts of nitrogen in surface layers of the soils under Sal–*Mallouts* community were higher than in soils of other communities studied. This further shows that nitrogen content of the soils is proportional to the amount of exchangeable calcium as is seen in Table III. Similar results were found in the study of Kulu hill forest soils (Puri and Gupta, 1951).

TABLE II

pH–class →	5·5	5·6–6·	6·1–6·5	6·6–6·8	Total No. of soils studied
Plant community ..	Number of soils for each p-H class				
Zizyphus jujuba ..	3	7	..	..	10
Carissa-Sapium ..	1	14	..	..	15
Sal-*Mallotus* ..	2	8	13	7	30

This study incidentally reveals that cultivated soils that are left fallow eventually become impoverished in soil calcium and nitrogen and become acidic both on the surface as well as in the subsoil under these climatic conditions. Forest cover even of a poor, malformed and stunted nature on the other hand not only maintains under these climatic conditions the supply of these nutrients in the soils, but perhaps improved their fertility status.

Some of the plants growing in the area were analysed for total calcium and results are given in Table IV.

It will be seen that leaves of *Adhatoda*, *Zizyphus*, *Woodfordia*, *Duranta*, etc., growing here contain higher amounts of calcium than those of *Sal*, *Mallotus* and *Hollarrhena*. This may show that low calcium status of the *Zizyphus* soils as recorded earlier may be partly due to the higher demands of these species on soil calcium. The

TABLE III

Profile No.	Ca in miliequivalents in upper layer of the soil	Percentage Nitrogen in upper layer of the soil
1	7·60	0·056
2	13·50	0·067
5	13·80	0·086
3	14·20	0·098
4	15·00	0·091
6	18·60	0·091
11	25·60	0·112
9	26·50	0·133
7	30·00	0·103
12	30·40	0·166
8	32·60	0·303
10	35·80	0·326

TABLE IV

Total Ca in Leaves of Given Species on Percentage of Air-Dry Leaf Material

	Species	Percentage CaO
1	*Mallotus philippinensis*	1·64
2	*Shorea robusta*	1·79
3	*Mangifera indica*	2·14
4	*Colebrookia oppositifolia*	2·60
5	*Hollarrhena antidysenterica*	2·63
6	*Duranta plumieri*	2·84
7	*Murrya koenigii*	2·87
8	*Woodfordia fruticosa*	2·94
9	*Zizyphus jujuba*	3·83
10	*Adhatoda vasica*	3·94

high calcium contents in surface layers of the Sal–*Mallotus* community may be due to all or either of the factors given below:

1. Replenishment of soil Ca by flood water of the river.
2. High calcium status of soils.
3. Low demands of calcium by Sal and *Mallotus* trees from the soil.

Low calcium content in surface layers of the soils as recorded under *Zizyphus* community may be due either to leaching or high demands of the plants growing in it. The later view may also explain the presence of low subsoil calcium in these soils.

It may be pointed out that foliar calcium in some of the species studied from this area is different from the same species that were

growing on better soils in the Dun Valley (Puri and Gupta, 1950). For example, *Adhatoda vasica* from poor soils of Tapkeshwar contained 3·94% CaO whereas this species growing on riverain soils of Lachhiwala contained 5·07% CaO. Similarly *Colebrookia* from Sal forests on clay contained 3·31% CaO and from this area it contained 2·60% CaO.

Hollarrhena antidysenterica from Lachhiwala forests contained 2·25% CaO, while from Tapkeshwar soils it had 2·63%. *Woodfordia fruticosa* from sal forests contained 2·30% CaO and in this area CaO in its leaves was 2·94%.

This may show that the amount of foliar calcium in one and the same species may be different on different soils and may perhaps be related to the calcium status of the soil.

Summary

The study of soils and vegetation on the terraces of the river Tons near Dehra Dun cantonment indicates that Sal–*Mallotus* community occurs on the conglomerate rock and not on terraces or riverain soils. These soils are acidic and contain relatively higher amounts of Ca and N. The soils of the terraces, which are abandoned cultivated lands, bear bio-edaphic communities of *Zizyphus jujuba* and *Carissa-Sapium*. These soils are more acidic and contain relatively lower amounts of Ca and N than the Sal–*Mallotus* soils. The poor condition of vegetation here is partly due to the unfavourable human influences and partly to soil conditions. The results thus agree with earlier conclusions of Puri (1950) regarding the growth and distribution of forest communities in the Dun Valley.

Literature Cited

Puri, G. S. 1950. Soil pH and forest communities in the Sal (*Shorea robusta* forests of the Dun Valley. Indian Forester. 76: 292–309.

——— and Gupta, A. C. 1950. The foliar ash and calcium in *Shorea robusta* and its associated vegetation in the Dun Valley. Jour. Ind. Bot. Soc. 29: 139–44.

———. 1951. Himalayan conifers. II. The ecology of humus in conifer forests of the Kulu Himalayas. Indian Forester. 77: 55–63 ; 124–29.

APPENDIX

Terrace	Profile No.	Depth in inches	N % of dry weight of the material	pH	CaO in mili equivalent	Vegetation, etc.
1	1	0	0·056	7·1	7·60	
		6	..	6·7	19·20	Cluster of about 36 mango trees (within 20 ft.—4 trees)
		12	..	6·2	20·80	
		24	..	5·6	26·20	
		36	..	5·5	28·00	
2	2	0	0·067	5·6	13·50	
		6	..	5·5	17·30	Many bushes of *Zizyphus jujuba* (within 20 ft.—25 bushes)
		12	..	5·6	23·40	
		24	..	5·6	23·00	
		36	..	5·6	21·80	
Slope I Aspect N	3	0	0·098	5·8	14·20	
		6	..	5·8	20·80	Open field (slope) uncultivated land
		12	..	5·7	17·80	
		24	..	5·8	21·00	
		36	..	5·8	20·40	
Terrace 3	4	0	0·091	5·7	15·00	
		6	..	5·6	28·70	Open field cultivated land
		12	..	5·5	27·00	
		24	..	5·5	27·70	
		36	..	5·6	24·90	
Slope 2 Aspect N	5	0	0·0868	5·8	13·80	
		6	..	5·7	24·20	Open field and slope
		12	..	5·6	14·10	
		24	..	5·6	21·60	
		36	..	5·3	21·60	
Terrace 4	6	0	0·091	5·7	18·60	
		6	..	6·0	21·60	Slope at the ridge of the river
		12	..	5·8	22·40	
		24	..	5·7	25·80	
		36	..	5·6	27·00	
Terrace 4, on the left side of the river Aspect S	7	0	0·1036	6·0	30·00	
		6	..	6·1	24·00	Within 20 ft. Sal-2 *Mallotus*-4
		12	..	6·1	22·20	
		24	..	6·2	24·00	
		36	..	6·1	22·80	
	8	0	0·3036	6·4	32·60	
		6	..	6·6	29·60	Within 20 ft. *Hollarrhena antidysenterica*-10
		12	..	6·6	25·80	
		24	..	6·7	24·70	
		36	..	6·8	28·20	
	9	0	0·133	6·6	26·50	
		6	..	6·4	26·50	Within 20 ft. Sal-5. *Mallotus*-10. *Hollarrhena*-2
		12	..	6·3	27·30	
		24	..	6·3	31·60	
		36	..	6·2	33·00	

Terrace	Profile No.	Depth in inches	N% of dry weight of the material	pH	CaO in mili equivalent	Vegetation, etc.
	10	0	0·326	6·5	35·80	
		6	..	6·6	32·00	Within 20 ft. Sal–2. *Mallotus*–7. *Hollarrhena*–1
		12	..	6·6	22·80	
		24	..	6·4	30·00	
		36	..	6·3	26·00	
	11	0	0·1127	6·2	25·60	
		6	..	5·8	32·80	Within 20 ft. Sal–2. (Open canopy)
		12	..	5·5	32·50	
		24	..	5·5	34·40	
		36	..	5·7	33·80	
	12	0	0·1666	6·0	30·40	Within 20 ft. *Mallotus*–7. Sal–6. *Hollarrhena*–5. *Carissa*–3, roots of various trees. (Covered canopy)
		6	..	6·0	25·80	
		12	..	5·8	28·90	
		24	..	5·7	32·40	
		36	..	5·7	30·70	

FIG. 1

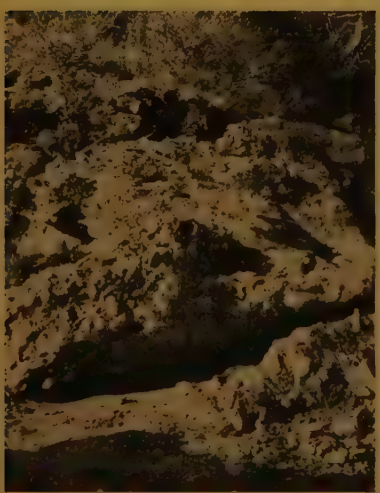

FIG. 2

FIG. 3

A. C. Gupta

THE AUTECOLOGY OF *ANISOCHILUS ERIOCEPHALUS* BENTH.

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Work in India on plant ecology has been mainly concentrated round synecology, and autecological problems have not received the same attention. A beginning, however, has been made by Misra and Siva Rao (1948).

The genus *Anisochilus* Wall. consists of 16 species all of which are confined to Asia (Hooker, 1885). Of these only two, *A. eriocephalus* Benth. and *A. carnosus* Wall. have been observed in Sagar. *A. eriocephalus* Benth. has so far been reported from the Kymore Hills of Bihar, the rocky Ghats from Konkan southwards and Bellary (Hooker, 1885). Haines (1922) has recorded it from Ranchi. *A. carnosus* Wall. is confined to the limestone rocks of Singhbum and Ranchi (Haines, 1922), the Western Himalayas, Kumaon and Garhwal, ascending to 8,000 ft. and extends through Central and Southern India to Travancore and Ceylon (Hooker, 1885). The two species, however, cannot be easily separated from one another. Hooker, Haines, and Mukerjee (1940) distinguish *A. eriocephalus* Benth. from *A. carnosus* Wall. on the basis of calyx which is villous and woolly in the former but is glabrous, shortly pubescent or ciliate in the latter. During the course of the present investigation it was, however, seen that these characters intergrade and their development is largely influenced by the nature of the substratum. Duthie (1911) has, therefore, rightly described them as synonyms of each other. Cooke (1908), on the other hand, considers *A. eriocephalus* Benth. as a variety of *A. carnosus* Wall.

A. eriocephalus Benth. grows abundantly in Sagar on house tops roofed with country tiles. It may be found sometimes on well drained soil also. The species is a herbaceous annual incapable of perennating by any underground parts. After a few showers of rain, the seedlings appear late in June in descending rows along the tiles, and grow in thick stands near the lower edge of roofs. The roots obtain support by bending to the inner side of the tiles. The vegetative period lasts from $1\frac{1}{2}$ to 2 months. Flowering commences in the third week of August and continues till mid October when defoliation begins. Upto the end of this month the spikes remain standing on drying stems. The roofs are now cleared of their vegetation for the Divali Festival. The plants are pulled out but their thinner roots usually remain behind embedded in between the tiles.

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* The work was done in the Department of Botany, University of Saugar.

The plant most often grows in pure stands but at times it may have the following associates: *Chloris virgata* Sw., *Dichanthium annulatum* Stapf., *Elephantopus scaber* L., *Eragrostis sp.*, *Euphorbia geniculata* L., *E. microphylla* Heyne, *Ficus religiosa* L. and *Tridax procumbens* L.

Morphology

Root—There is a normal tap root system about 12–16 cms. in length with a dense network of secondary and tertiary branches which spread in between the overlapping tiles.

Stem—Erect, attaining an average height of 60–90 cms., the maximum being 1 metre, stout, pubescent, branching from the base.

Leaves—Rather thick, petioles 5 cms. long, orbicular, ovate, obtuse, cordate, crenate, crenation shallow, lamina about 5–7 cms. long and 5 cms. broad, puberulous on both surfaces and glandular beneath.

Spikes—Many, very dense, cylindric, on long slender peduncles.

Flowers—Small, zygomorphic, pale lilac.

Calyx—Suberect, inflated below the middle, bilipped, upper lip broadly ovate-acuminate, deflexed in fruit concealing the mouth and the truncate lower lip, tube inflated in the middle and curved, villous with long hairs.

Corolla—Pale lilac, bilipped, tube slender, decurved, throat inflated, upper lip short, entire, lower elongated.

Andræcium—Stamens 4, didynamous, filaments free.

Gynæceum—Ovary superior, bilocular, divided by false septa into one-seeded nutlets; style bifid.

Disc—Lobed.

Pollination—Entomophilous.

Fruit—A carcerulus, fruiting calyx with upper lip large.

Seeds—Oval, many but not too minute.

Seeds and Their Germination

1. *Size and Weight*—The seeds are oval but in a cross-section they appear triangular with slightly concave sides and blunt angles. The average length and breadth of a seed is 1·03 mm. and 0·88 mm. respectively. The average shape index as indicated by the Length/Breadth ratio is 1·02. The average weight of a seed is 0·000183 gm. This is considerably low but lighter seeds such as those of *Lidenbergia polyantha* Royle (Misra and Siva Rao, 1948), *Mollugo cerviana* Ser. and *M. nudicaulis* Lam. (Bakshi and Kapil, 1953 *a* & *b*) are on record.

2. *Seed Output*—The total seed output of a spike can be found either by weighing all the seeds produced by it and then dividing this by the average weight of a single seed or by actually counting the whole lot of seeds. Both these methods are extremely difficult in *Anisochilus eriocephalus* Benth. where the fruits mature acropetally, the entire

process being spread over a period of 6–7 weeks. A third method was, therefore, tried, taking advantage of the fact that each fruit generally produces 4 seeds. The number of fruits in spikes of mature plants were counted. Multiplying this by 4 gave the number of seeds. Care was, however, taken to eliminate unfertile flowers which were mostly found at the top of each spike. Counting was done in about 40 fully-grown plants of all sizes from different localities and the average seed output per plant was found to be 26,535 (Table I).

TABLE I

Seed output of Anisochilus eriocephalus *Benth.*

No.	Locality	No. of spikes per plant	Av. no. of seeds per spike	Seed output per plant
1	Sadar	46	320	14,720
2	do	123	464	57,072
3	do	21	398	8,358
4	do	81	416	33,696
5	Ata	141	316	44,556
6	do	129	332	42,828
7	do	22	380	8,360
8	do	159	400	63,600
9	Gopalgunj	46	320	14,720
10	do	51	304	15,504
11	do	61	356	21,616
12	do	41	388	15,908
13	Parkota	51	304	15,504
14	do	63	332	20,916
15	do	68	368	25,026
16	do	59	376	22,184

Average seed output per plant : 26,535

3. *Percentage Germination of Seeds*—Seeds collected in November, 1947, were used in experiments conducted in April and May, 1948, both in light and in dark. By "light" is meant the diffuse daylight received inside the laboratory through the windows. The "light period" thus included about 10–11 hours of darkness at night. "Dark period", on the other hand, indicates continuous total darkness.

Ordinarily the percentage germination was found to be 0·2 in dark and 6·2 in light (Table II). The germination in dark started on the 6th day and in light on the 4th day. When, however, the soaked seeds were first kept in continued darkness for 6 days and then exposed to light, the percentage germination increased to 12·2. This gave an impetus for further investigation in that direction and a number of experiments were carried out. The details of the results have already been communicated in a short note (Bakshi, 1952). Suffice it, therefore, to say that the period of preliminary continued darkness had a very marked effect on the percentage germination which increased with the increase in this "dark period" (Fig. 1). The optimum "dark period" for which the germination was 13·4 per

TABLE II

Number of seeds of Anisochilus eriocephalus *Benth. germinating each day out of* 500 *seeds*

Date	In light	In dark
10–4–1948 ..	16	0
11–4–1948 ..	11	0
12–4–1948 ..	3	1
13–4–1948 ..	1	0
Total ..	31 (6·2%)	1 (0·2%)

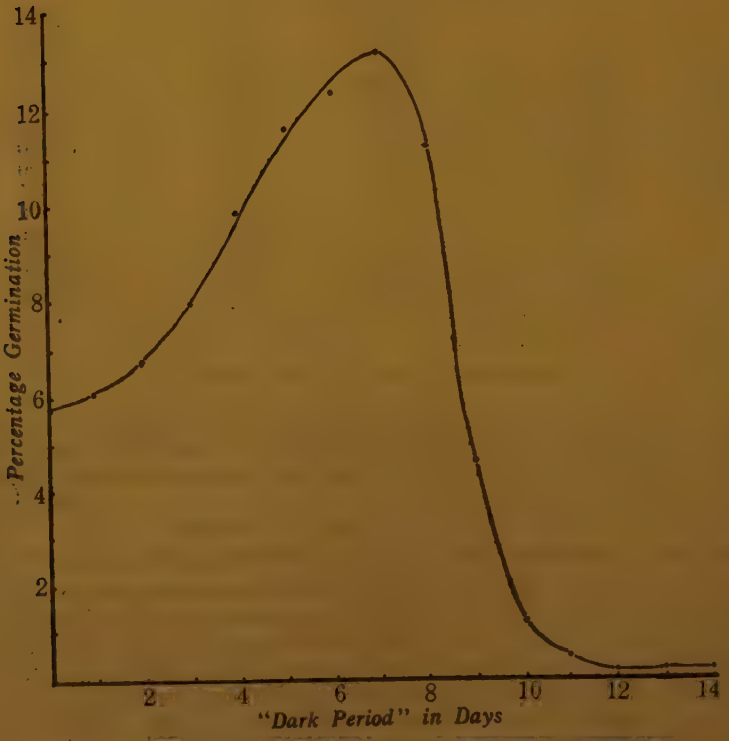

FIG. 1. Effect of "Dark Period" on percentage germination

cent., was found to be 7 days. After this the percentage fell sharply and declined to 0·2 on the 12th day. An almost similar case has been reported in *Lythrum salicaria* (Lehmann, 1918, quoted in Stiles, 1950) where an exposure of the seeds previously kept in dark to

a light intensity of 730 metre candles for just 0·1 second increased the germination from 7 per cent. to 50 per cent. It may, therefore, be concluded that light by itself stimulates the percentage germination of the seeds of *Anisochilus eriocephalus* Benth. in so far as it increases it from 0·2 in dark to 6·2 but a further increase can be obtained when the seeds are *subjected to a preliminary period of darkness.* Hence, the influence of light on germination must be considered in relation to other factors.

4. *Mortality Rate among Seedlings*—In nature the seedlings appear late in June. All of them, however, do not grow up into adult plants. Their mortality rate was studied on three equally sloping roofs. An area of 1 sq.ft. was marked out on each roof and the counts were made at regular intervals. The data along with the remarks on weather are given in Table III. It will be seen that the average percentage of the surviving seedlings is 7·7. The rest of the plants are either washed out by torrential rains or dried up in droughts of 2–4 days.

TABLE III

Number of seedlings of Anisochilus eriocephalus *Benth. surviving in 1 sq.ft. area on three roofs, A, B and C*

Date	Seedlings counted at			Remarks on weather
		B	C	
2–7–1948 ..	305	503	611	No rains from 2–7–1948 to 8–7–1948
6–7–1948 ..	163	317	429	
10–7–1948 ..	81	193	187	Light showers on 9–7–1948
12–7–1948 ..	73	181	153	Moderate rain on 11–7–1948
14–7–1948 ..	72	175	151	
16–7–1948 ..	47	39	56	No rain after 11–7–1948
17–7–1948 ..	36	38	48	Few showers
18–7–1948 ..	35	38	48	Few more showers
19–7–1948 ..	35	38	48	Light drizzle
22–7–1948 ..	29	36	41	Torrential rain on 20–7–1948 and 21–7–1948
Percentage of survived seedlings	9·5	7·0	6·7	Average : 7·7 per cent.

5. *Reproductive and Aggressive Capacity of the Plant*—The average reproductive capacity of a species has been defined by Salisbury (1942) as the product of the average seed output and the fraction represented by the average percentage germination. Since *A. eriocephalus* Benth. does not propagate by any means other than its seeds, its average reproductive capacity works out to about 1,645. This has been compared with the respective figures for a few other species in Table IV.

The potentiality of a species to spread and colonise may be described as its Aggressive Capacity and it can be represented by

TABLE IV

Reproductive capacity of some plants

Species	Av. seed output	Percentage germination	Reproductive capacity	Authority
Anisochilus eriocephalus Benth.	26,535	6·2	1,645	Author
Hypericum actum Moench ..	23,000	66·0	18,454	Salisbury
Lindenbergia polyantha Royle	71,731	98·0	70,266	Misra and Siva Rao
Mollugo cerviana Ser. ..	1,711	46·0	787	Bakshi and Kapil
Mercuriallis perennis L. ..	300	5·0	15	Salisbury

the product of its average reproductive capacity and the average percentage survival of the seedlings in its natural habitat. For *A. eriocephalus* Benth. it amounts approximately to 127. This is considerably low when compared with the high reproductive capacity of the plant. It, therefore, supports the presumption of Salisbury (1942) that the reproductive capacity of plants is correlated with the risks of mortality. If a similar relation could be established for a number of species, the "numerical values representing the reproductive capacity of species" would at once be counted in the "front rank of biological data". Since data for seedling mortality for other species are not available, it is difficult to calculate their aggressiveness to compare with that of *A. eriocephalus* Benth. but the figure appears to be large enough to ensure rapid spread of the plant provided the ecesising factors remain favourable.

6. *Dispersal of Seeds*—The calyx in the species is deflexed in the fruit. The seeds are, therefore, discharged downwards on roofs from where they can easily roll down or be blown to be lodged into crevices in between the tiles on other roofs. The plants shed most of their leaves by the time the seeds are ripe and the long-peduncled spikes are thus fully exposed to wind. This together with the lightness of the seeds and the height of the roof help considerably in an efficient wind dispersal of seeds. Rains may also wash them down and carry them to different places but this may not be very effective as the seeds become sticky when moist. Occasionally ants have also been seen carrying the seeds.

ENVIRONMENTAL FACTORS OPERATING UPON THE PLANT

1. *Climatic Factors*—According to the records (*Anonymous*, 1906), Sagar receives an average annual rainfall of 48 inches of which 7 inches are received in June, 16 inches in July, 12 inches in August, 7–8 inches in September and about an inch in October. The average during the 7 dry months is 2½ inches. The maximum annual rainfall amounting to 120 inches was recorded in 1858 and the minimum of 17 inches in 1892–93. No further records of the climate of the area

are available till 1948 when the figures for rainfall and maximum and minimum temperatures were recorded by Pandeya (1949). The data are reproduced in Table V. The total rainfall for 1948 was 61·5 inches which is well above the average given in the *Gazetteer* of Sagar. The rainfall has exceeded 50 inches in 16 out of 32 years (*Anonymous*, 1906). This, together with the figure for 1948, gives an indication of a slow yearly increase in the rainfall of Sagar.

TABLE V

Monthly average records for rainfall and temperature of Saugar University for 1948

Month	Rainfall in inches	Temperature in degrees F.	
		Maximum	Minimum
January ..	0·65	70·7	53·6
February ..	..	77·0	57·0
March ..	0·30	88·2	65·5
April ..	..	102·5	78·0
May ..	0·30	107·5	84·4
June ..	11·00	97·5	81·6
July ..	18·63	85·0	77·1
August ..	17·37	82·5	74·5
September ..	5·95	84·5	73·3
October ..	0·80	88·0	71·5
November ..	6·50	74·0	60·5
December ..	..	72·0	53·5

The vegetative growth of *A. eriocephalus* Benth. is active in July and August when the monthly rainfall ranges between 17 and 19 inches and the average maximum and minimum temperatures for these two months are 84·4° F. and 75° F. respectively. The same conditions of temperature continue in September when the spikes appear and the flowers open. The rainfall, however, decreases considerably but by now the plants are fully mature needing little water for actual vegetative growth. The seeds ripen in the following drier period. The climatic conditions are, therefore, ideal for the germination and growth of *A. eriocephalus* Benth.

2. *Physiographic Factors*—The slope and height of roofs prevent waterlogging and lessen the pressure of destructive biotic factors considerably thus ensuring the healthy growth of the species.

3. *Edaphic Factors*—The thin layer of dark brown soil on the roofs has a spongy texture due to the half decomposed organic matter and humus being present in it. This helps in good aeration of soil and in easy penetration of the roots. Soil samples were collected in cigarette tins and the analysis was done as described by Misra (1944). The moisture content and the chemical analysis of the soil samples are given in Tables VI and VII respectively. It will be seen that

TABLE VI

Percentage moisture content of soil samples at different localities

Date	Locality	Water content % of dry wt.	Remarks
7-5-1948	Sadar	0·90	Soil samples collected before the outbreak of monsoons
do	Gopalgunj	1·03	
do	Parkota	0·58	
do	Chakraghat	0·96	
21-7-1948	Sadar	34·00	Samples collected on a rainy day when the soil was saturated with water
do	Gopalgunj	29·83	
do	Parkota	33·46	
do	Chakraghat	30·64	
8-8-1948	Sadar	21·10	Heavy rain on 7-8-1948 but little on 8-8-1948
do	Gopalgunj	20·36	
do	Parkota	21·64	

TABLE VII

Characters of soil samples collected from 12 localities in Sagar

No.	Carbonates	Nitrates	pH	Ammonium thiocyanate test		
				Without H_2O_2	With H_2O_2	Reductivity
1	+	+	8·0	–	–	0
2	+	+	7·0	–	–	0
3	+	++	6·5	–	–	0
4	+	+	7·5	–	–	0
5	–	++	7·0	–	–	0
6	–	+	7·0	–	–	0
7	–	++	7·5	–	–	0
8	+	++	8·0	–	–	0
9	+	++	6·0	–	–	0
10	–	+++	6·0	–	–	0
11	–	++	6·5	–	–	0
12	–	+++	7·5	–	–	0

the water content of the soil is usually high and, unlike the soils for *Lindenbergia polyantha* Royle (Misra and Siva Rao, 1948), it does not vary appreciably in different localities at a particular time. This is chiefly on account of the organic colloids in the soil and similarity in its texture throughout. The pH value ranges between 6 and 8. The nitrate content does not show any relation with the incidence of the species. The presence of carbonates is negligible and the reductivity value is zero. The species, therefore, does not appear to be either nitrophilous or calcicolous.

4. *Biotic Factors*—Clearings by man and interspecific competition are the only destructive biotic factors operating against the plant on roofs. At the time of Divali festival the roofs are cleared of all

vegetation but this does not seem to affect the plant as by this time the dispersal of the seeds has already occurred. The interspecific competition also does not appear to be acute as the associates of *A. eriocephalus* Benth. are less aggressive on house tops where the conditions for their growth are probably unsuitable.

Culture Experiments

The following three sets of culture experiments were conducted in order to test the validity of the assumptions made in the previous pages as regards the effect of the nature of soil, waterlogging and interspecific competition on the germination and growth of the species.

Experiment A—Seeds from the same lot were sown in 5 pots, numbered I–V, containing loam, garden soil, calcium-rich soil, powdered tiles and sand respectively. All the pots were placed in the open. They were watered twice a day and were kept free of weeds.

Seedlings appeared in all the pots about 4 days after sowing. In sandy soil they died after making a stunted growth for about a month. Plants in pots III and IV showed almost equal, though unhealthy growth and flowered early. In pot I the plants grew vigorously and flowered 9 days later. The plants in pot II were half as tall as those in pot I. The relative growths in all these cases have been compared in Fig. 2.

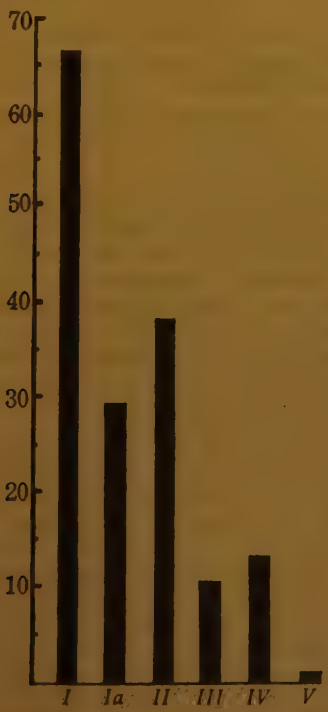

Fig. 2. Comparative growth in centimetres of plants grown in pots I–V

It is interesting to note that while the plants in pot I resembled *A. eriocephalus* Benth. those in pots III and II showed the characters of *A. carnosus* Wall. and its variety, *purpurescence* Benth., respectively.

Experiment B—Seeds were germinated in two pots, I and I *a*, both containing loam. Pot I was kept free of weeds and in pot I *a* weeds were allowed to grow. The relative growth of plants in the pots was observed for about 3 months and it was seen that interspecific competition has a deleterious effect on the growth of the species (Fig. 2).

Experiment C—Seeds were sown in 3 pots each containing loam. In one water was always kept upto the brim, in the second soil was continuously kept saturated with water and in the third case, the pot was watered moderately twice a day. Seedlings appeared only in the third pot. A similar experiment was conducted with one month old plants growing on loam. The result was again the same and all the plants in the first 2 pots died within 4 days of waterlogging.

These culture experiments are significant in explaining the occurrence of healthy plants of the species on roofs and its depauperate form on the ground below. The favourable factors on roofs include a well aerated soil rich in organic matter, sufficient water stored in the porous and organic soil with no possibility of waterlogging and little interspecific competition.

Discussion

Notwithstanding its high reproductive and aggressive capacity the geographical and ecological distribution of *Anisochilus eriocephalus* Benth. is considerably limited.

The narrow geographical distribution of the species appears to be related to the lack of continuity of favourable climatic areas. The chief features of the climate are its periodic nature including a summer monsoon and an average maximum and minimum temperature of 84° F. and 75° F. respectively. Prolonged periods of drought and lower temperature evidently kill the plants.

The important features of the habitat are its slope and elevation from the ground and the nature and texture of the soil. These help the species by maintaining proper drainage, better aeration, least interspecific competition, suitable substratum rich in organic matter and an advantageous height for efficient wind dispersal.

Under normal environmental conditions it has been found that the percentage germination of the seeds is very low and the rate of mortality among the seedlings very high. These factors coupled with the requirements of a special habitat have kept the species restricted to a narrow area. The barriers are, thus, both ecological and geographical.

Hooker (1885) considers that *A. eriocephalus* Benth. is a depauperate form of *A. carnosus* Wall. Both he and Haines (1922) distinguish the two species by calyx which is woolly in the former but glabrous, shortly pubescent or ciliate in the latter. In culture experiments it was, however, seen that these characters are not stable. The woolly calyx of plants growing on loam seemed to have changed to the shortly

pubescent type in plants growing on calcium-rich soil and in stray cases, the calyx actually became glabrous. It was as if the closely growing epidermal appendages of the calyx in *A. eriocephalus* Benth. became scattered and shorter as the plant grew in a stunted form on calcium-rich soil and ultimately disappeared thus giving rise to the glabrous calyx of *A. carnosus* Wall. This indicates that the distances between the epidermal appendages of the calyx, the differences in their lengths and even their complete absence are not characters sufficient to warrant the separation of the two plants into two distinct species. One can easily obtain the desired form by growing the plants on appropriate soil. An analogy to this case is offered by *Lindenbergia polyantha* Royle. After a thorough investigation Misra and Siva Rao (1948) came to the conclusion that *L. polyantha* Royle and *L. urticæfolia* Link and Otto are ecotypes of the same species, the former, found growing on calcium-rich soil, being a starved form of the latter. The point of difference between the two cases is that whereas in *Anisochilus eriocephalus* Benth. the disputed point is the woolly or glabrous nature of the calyx, in *Lindenbergia polyantha* Royle the confusion was centred round the epidermal appendages of the corolla and the size of the leaves.

It may be pointed out that it is the plants growing in a stunted form on calcium-rich soil which resembled *Anisochilus carnosus* Wall. Haines (1922) has also observed the species growing on the limestone rocks of Singhbum and Ranchi. Hence it is *A. carnosus* Wall. which is the starved form of *A. eriocephalus* Benth. and not *vice versa* as Hooker (1885) records. Further, Cooke (1908) considers *A. eriocephalus* Benth. as a variety of *A. carnosus* Wall. but in view of the above observations, the latter can more justifiably be regarded as a variety of the former.

A point of interest about *A. carnosus* Wall. is the unstable nature of its varieties. Hooker (1885) describes var. *purpurescence* Benth. as having "narrow cylindric spikes", "purple flowers" and "shorter calyces". The plants growing on garden soil showed all these characters though the presence of shorter calyces could not be definitely established. The varieties *glabrior* and *villosior* Benth. have their calyces glabrous and villous respectively. These characters, as shown above, are not dependable. A fourth variety, *viridis* Benth. (*A. rupestris* Wight), has been described by Hooker (1885) as being "founded on an immature plant with the habit of *A. eriocephalus* Benth." It was, therefore, the variable nature of these varieties which led him to state that he failed to distinguish them by "good characters".

In conclusion it may be stated that *A. carnosus* Wall. together with its varieties is not different from *A. eriocephalus* Benth. in morphological characters. Both are, therefore, the ecotypes of the same species, the former being the starved form of the latter.

Summary

1. The present work deals with the autecology of *Anioschilus eriocephalus* Benth. which grows abundantly on house tops roofed with country tiles.

2. The average seed output per plant is 26,535. The seeds produced are minute and light and are easily disseminated by wind. The percentage germination is as low as 6·2 but it increases to 13·4 if the soaked seeds are kept in dark for 7 days and then exposed to diffuse light. The average reproductive capacity per plant is 1,645. The mortality rate among the seedlings is, however, very high, being 92·3 per cent. The aggressive capacity of the species is thus 127.

3. In nature the seedlings appear late in June. Flowering commences in the third week of August and viable seeds can be obtained by the middle of November.

4. The climate of Sagar suits the plant well. The slope and elevation of roofs prevent waterlogging and lessen biotic pressure.

5. The thin layer of soil on house tops is well aerated. It is spongy and is rich in organic matter. Its pH value ranges between 6 and 8. The plant is neither nitrophilous nor calcicolous.

6. The species is restricted to a narrow area and the barriers have been shown to be both ecological and geographical.

7. It has been concluded on the results of culture experiments and analytical data that *Anisochilus carnosus* Wall., together with its varieties, is not different from *A. eriocephalus* Benth. in morphological characters and that they are ecotypes of each other.

Acknowledgement

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Literature Cited

Anonymous. 1906. Gazetteer, Sagar District, A. Volume Descriptive, Allahabad.

Bakshi, T. S. 1952. The effect of a preliminary period of darkness on the percentage germination of the seeds of *Anisochilus eriocephalus* Benth. Curr. Sci. **21**: 108.

——— and Kapil, R. N. 1953 *a*. The autecology of *Mollugo cerviana* Ser. (In Press).

————. 1953 *b*. The autecology of *Mollugo nudicaulis* Lam. (In Press).

Cooke, T. 1908. Flora of Bombay Presidency. Vol. II. London.

Duthie, J. F. 1911. Flora of the Upper Gangetic Plain. Vol. II. Calcutta.

Haines, H. H. 1922. The Botany of Bihar and Orrissa. Part IV. London.

Hooker, J. D. 1885. The Flora of British India. Vol. IV. London.

Lehmann, E. 1918. Uber die minimale Blichtungskeit welche die Keimung der Samen von *Lythrum Salicaria* auslost. Ber. deut. bot. Ges. **35**: 157–62.

Misra, R. 1944. The soil complex as studied in plant ecology. J. Benares Hindu Univ. **9**: 13–16.

——— and Siva Rao, B. S. 1948. A study in the autecology of *Lindenbergia polyantha* Royle. J. Indian bot. Soc., **28**: 186–99.

Mukerjee, S. K. 1940. A revision of the Labiatae of the Indian Empire. Records Bot. Surv. India. **14**.

Pandeya, S. C. 1949. Vegetation of the plateau of Saugar University. M.Sc. Thesis, University of Saugar.

Salisbury, E. J. 1942. The reproductive capacity of plants. London.

Stiles, W. 1950. An introduction to the principles of plant physiology. London.

SULPHUR AND NITROGEN REQUIREMENTS OF THE GENUS *PYTHIUM*

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Introduction

The importance of proper source of carbon, nitrogen, sulphur and other elements in a synthetic medium for the growth of fungi is now well known. Earlier papers from this laboratory (Saksena, 1940; Saksena and Bhargava, 1941; Bhargava, 1945 *a*, *b*, *c*; and Saksena and Mehrotra, 1949) have demonstrated their value for some species of *Pythium* and members of the family Saprolegniaceæ. An unsuitable source of sulphur, for example, may lead to erroneous results as was indicated by Bhargava (1945 *b*, p. 344). The senior author (Saksena, 1940) studied the nutrition of five species of *Pythium* qualitatively. It was decided to extend this study to some more species and to make a quantitative determination of the sulphur and nitrogen requirements of *Pythium afertile* Kanouse et Humphery, *P. aphanidermatum* (Edson) Fitz., *P. arrhenomanes* Drechs. var. *canadensis* Vanterpool et Truscott, *P. artotrogus* (Mont.) de Bary, *P. deBaryanum* Hesse var. *pelargonii* Braun, *P. deliense* Meurs, *P. polyandron* Sideris. In addition *P. diameson* Sideris, *P. leucosticton* Sideris, *P. mamillatum* Meurs, *P. rhizophthoron* Sideris, *P. spaniogamon* Sideris, and *P. scleroteichum* Drechsler were also tried in experiments dealing with nitrogen requirements.

Methods

The methods in general were similar to those followed in earlier works (Saksena, 1940; Bhargava, 1945 *a*, *b*). For experiments on sulphur requirements, the fungi were grown in Erlenmeyer flasks on the basal medium to which various sulphur compounds had been added singly so as to furnish 25 mg. of sulphur per litre. The basal medium, which will hereafter be referred to as medium A in experiments dealing with sulphur requirements consisted of 0·5 gm. of KH_2PO_4, $MgCl_26H_2O$, 2 gm. of NH_4NO_3, 5 gm. of dextrose and 1,000 c.c. of double-distilled water.

Nitrogen requirements of the fungi were studied by growing them on a basal medium to which various nitrogenous compounds had been added singly so as to furnish 500 mg. of nitrogen per litre. The basal medium, which will later be referred to as medium B consisted of 0·5 gm. of KH_2PO_4, $MgCl_2$ $6H_2O$ and K_2SO_4, 5 gm. of dextrose and 1,000 c.c. of double-distilled water. $MgCl_26H_2O$ was prepared by the action of pure HCl on clean magnesium ribbon, the commercial reagent grade chemical being of no value in these experiments as it

TABLE I

Dry Weight (in mg.) of the Fungal Colonies Grown on Medium A With and Without Sulphur Compounds

(Time of incubation = 21 days)

Fungi	Medium A	Sulphur Compound											
		Potassium sulphate	Sodium sulphide	Sodium hypo-sulphite	Sodium bi-sulphite	Potassium per-sulphate	Sodium thio-sulphate	Sodium meta-bi-sulphite	Sodium dithio-nate	Sodium sulphite	Hydrogen sulphide	Thio-urea	Cystein Hydro-chloride
P. afertile ..	1·5	16·3	10·0	8·2	24·0	14·0	29·5	24·0	2·0	16·0	5·0	25·0	29·0
P. aphanidermatum ..	2·5	18·3	12·5	12·1	34·0	25·0	31·5	26·5	2·5	32·0	29·0	25·0	30·0
P. arrhenomanes v. *canadensis*	1·5	22·5	31·5	23·0	31·0	24·0	44·0	23·0	1·5	15·0	23·0	22·0	35·0
P. artotrogus ..	1·4	19·0	15·0	13·1	17·0	10·0	30·1	16·2	1·5	12·0	10·0	15·0	16·0
P. deBaryanum var. *pelargonii*	3·0	25·7	21·2	6·4	11·0	25·0	28·0	10·2	3·0	24·0	16·5	16·0	28·0
P. deliense ..	1·0	18·5	8·6	10·0	18·5	12·5	20·0	14·2	1·0	14·0	12·0	16·0	16·0
P. polyandron ..	2·8	13·3	13·0	22·0	28·0	23·5	37·0	30·0	3·0	26·0	19·0	20·0	28·5

contained traces of ammonia. The presence of ammonia in the medium after the incubation period was detected by Nessler's reagent.

All the experiments were carried on at 25° C.

Observations

Sulphur Requirements

To the basal medium A, the following sulphur compounds were added singly, before autoclaving. Medium A alone served as control.

Potassium sulphate, sodium sulphide, sodium hyposulphite, sodium bisulphite, potassium persulphate, sodium thiosulphate, sodium metabisulphite, sodium dithionate, sodium sulphite, hydrogen sulphide, thio-urea and cystein hydrochloride. In the case of hydrogen sulphide, the gas was passed for 5 mts. through 200 c.c. of the basal medium. The pH of the medium was adjusted to 6·5 in each case. Medium A with and without the addition of various sulphur compounds was inoculated with the fungi. Dry weights of the colonies were determined after an incubation period of 21 days. The results are tabulated in Table I.

The results summarised in this table indicate that the fungi show traces of growth even in the basal medium A. Of the various compounds tried sodium thiosulphate supported the maximum growth in all cases except *P. aphanidermatum*. Sodium dithionate was the only compound which was not utilised at all by the organism tried. Other compounds proved to be good sources of sulphur.

Nitrogen Requirements

To the medium B, the following nitrogen containing compounds were added singly, before autoclaving:

Inorganic.—Ammonium chloride, potassium nitrate, sodium nitrate, sodium nitrite.

Organic.—*d*-Alanine, glycine, asparagin, *d*-glutamic acid, acetamide and urea.

The pH of the medium was adjusted to 6·5 in each case. The various media thus obtained were inoculated with the fungi. The basal medium B alone served as control. After an incubation period of 15 days, the dry weight of the colonies and the pH of the medium were measured. The results are tabulated in Table II. Since there was no growth on media containing nitrites, they have not been included in Table II.

Of the six organic compounds taken for study, acetamide supported the least growth in most of the species tried. *P. arrhenomanes*, *P. artotrogus*, *P. deBaryanum*, *P. deliense*, and *P. diameson* were unable to utilise it at all. Sodium nitrate, amongst the inorganic nitrogen compounds, was fairly good, but ammonium chloride proved to be a mediocre source for the supply of nitrogen. There was no growth in medium B which was lacking in nitrogen.

In most cases the pH of the medium showed a rise except in media containing ammonium chloride or acetamide, where they had become acidic after incubation.

TABLE II

Dry Weight (in mg.) of the Fungal Colonies Grown on Medium B With and Without Nitrogen Compounds

(Incubation period = 15 days)

Figures in brackets show the pH of the medium after incubation

Fungi	Nitrogen compounds								
	Medium B	Acetamide	Alanin	Ammonium chloride	Asparagin	Glutamic acid	Glycine	Sodium nitrate	Urea
P. afertile	0	2·6 (3·6)	24·66 (7·6)	3·7 (3·8)	32·7 (7·4)	26·6 (7·6)	18·0 (7·1)	20·2 (7·4)	0 (7·1)
P. aphanidermatum	0	12·0 (6·4)	30·0 (7·5)	10·0 (4·0)	26·0 (7·6)	18·0 (7·8)	20·66 (7·6)	16·66 (7·8)	14·66 (7·6)
P. arrhenomanes	0	0·0 (6·6)	28·86 (7·8)	2·3 (3·8)	23·2 (7·7)	18·3 (7·8)	22·3 (7·8)	10·0 (7·8)	15·0 (7·2)
P. artotrogus	0	0·0 (6·4)	15·0 (7·4)	3·0 (4·0)	26·66 (7·8)	41·0 (7·8)	33·33 (7·8)	31·66 (7·3)	22·66 (7·5)
P. deBaryanum	0	0·0 (6·4)	34·66 (7·7)	6·0 (4·6)	32·66 (7·3)	31·66 (7·8)	34·0 (7·5)	33·16 (7·3)	19·9 (7·6)
P. deliense	0	0·0 (6·4)	32·33 (7·8)	12·3 (3·6)	36·66 (7·8)	24·66 (7·6)	31·0 (5·8)	24·66 (7·8)	20·5 (8·3)
P. diameson	0	0·0 (6·4)	21·23 (7·8)	7·33 (3·9)	33·2 (7·8)	20·5 (7·8)	21·0 (7·8)	23·0 (7·8)	11·5 (7·6)
P. leucosticton	0	2·0 (4·7)	17·6 (7·8)	10·0 (4·0)	6·0 (6·2)	14·0 (7·6)	16·06 (8·0)	13·46 (7·6)	13·5 (7·8)
P. mamillatum	0	4·23 (4·1)	15·66 (7·8)	6·0 (3·8)	16·0 (7·3)	15·0 (6·3)	24·0 (7·8)	9·7 (7·8)	10·0 (7·6)
P. polyandron	0	8·5 (5·3)	28·66 (7·6)	8·3 (3·6)	35·5 (7·6)	28·0 (7·6)	24·0 (7·8)	33·5 (7·2)	15·0 (7·6)
P. spaniogamon	0	1·0 (5·4)	30·0 (7·6)	10·86 (3·6)	30·93 (7·6)	30·0 (7·6)	29·4 (7·6)	13·3 (7·6)	29·06 (7·8)
P. sclerotiolum	0	7·46 (5·5)	20·2 (7·5)	2·3 (3·8)	24·1 (7·6)	20·63 (7·6)	22·5 (4·7)	24·56 (7·0)	22·1 (7·2)
P. rhizophthoron	0	3·0 (5·6)	27·3 (7·6)	8·0 (3·8)	28·3 (7·8)	19·06 (7·8)	22·2 (7·6)	16·83 (7·6)	11·25 (7·8)

DISCUSSION

The growth of the organisms obtained on medium A is very little as compared to other compounds. It seems that it is due to the

traces of sulphur (0·002%) present as impurities in the form of sulphates in $MgCl_2$ and NH_4NO_3 used. It is, therefore, clear that the organisms are unable to grow in a synthetic medium in the absence of sulphur. Since the amount of growth supported by sodium dithionate is also nearly equal to that obtained on the basal medium, it is concluded that sodium dithionate does not supply sulphur to these organisms. The species under investigation are able to obtain sulphur from sulphates, therefore, they fall under the category of "Euthiotrophe" of Fischer (Lwoff, 1932) and resemble other species of *Pythium* investigated by the senior author (Saksena, 1940).

That nitrogen is equally important for the growth of the organisms is evident from the results obtained in Table II, which show that they failed to grow in medium B lacking in a source of nitrogen.

Of the various species tried, none showed any growth in media containing nitrites as source of nitrogen, nitrite nitrogen has been found to be toxic for fungi even in dilute doses. Leonian and Lilly (1934) tried 25 fungi and only *Blakeslea trispora* showed growth with sodium nitrite as source of nitrogen.

Since the fungi studied above can assimilate nitrogen from sodium nitrate, ammonium chloride or a single amino acid, it can be stated that they are able to manufacture their own amino acids from these substances. Leonian and Lilly (1930) have also recorded that *Pythium oligandrum* and *P. polymastum* in addition to several others studied by them require only one favourable amino acid as the source of nitrogen for good growth. The present observations are in general agreement with those of the senior author (Saksena, 1940) on some species of *Pythium* and show that these fungi fit well in the "nitrate ammonium organisms" group of Robbins (1937).

The pH value has gone high in media containing alanin, asparagin, glutamic acid, glycine, sodium nitrate and urea. It can well be explained by assuming that during the growth of fungus breaking down of the nitrogenous compounds and the consequent accumulation of ammonia has caused this rise. Quantitatively this has been confirmed by the Nessler's test because all the media which showed a rise in pH after incubation gave the characteristic precipitate with Nessler's reagent.

Summary

Various species of *Pythium* tried are capable of utilising sulphur from organic as well as inorganic sources. Since they can obtain sulphur from sulphates they fall under the category of "Euthiotrophe" of Fischer. They fail to grow in nutrient solutions lacking in sulphur or nitrogen. They are capable of assimilating nitrogen from sodium nitrate, ammonium chloride or a single amino acid but not from nitrites. Rise in pH after incubation is shown to be due to the accumulation of ammonia.

References

BHARGAVA, K. S. 1945 *a*. Physiological studies on some members of the family Saprolegniaceæ, II. Sulphur and phosphorus requirements. Proc. Indian Acad. Sci. B 21: 344–49.

————. 1945 *b*. Physiological studies on some members of the family Saprolegniaceæ, III. Nitrogen requirements. Journ. Indian bot. Soc. 24: 67–72.

————. 1945 *c*. Physiological studies on some members of the family Saprolegniaceæ, IV. Carbohydrate requirements. Lloydia. 8: 60–68.

LEONIAN, L. H. AND LILLY, V. G. 1938. Studies on the nutrition of fungi, I. Thiamin, its constituents and the source of nitrogen. Phytopath. 28: 531–48.

LWOFF, A. 1932. La nutrition des Protozonires. Monogr. Inst. Pasteur. Paris.

ROBBINS, W. J. 1951. Assimilation by plants of various forms of nitrogen. Amer. Jour. Bot. 24: 243–50.

SAKSENA, R. K. 1940. The nutrition of some species of the genus *Pythium* on synthetic liquid media. Proc. Nat. Acad. Sci. India. 10: 1–13.

——— AND BHARGAVA, K. S. 1941. A physiological study of *Saprolegnia delica* Coker. Ibid. 11: 27–40.

——— AND MEHROTRA, B. S. 1949. Carbon requirements of the genus *Pythium*. Ibid. 19: 1–11.

BRACHYPHYLLUM SPIROXYLUM SP. NOV. FROM THE RAJMAHAL HILLS, INDIA

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Introduction

The form genus *Brachyphyllum* was instituted by Brongniart who in 1828 described a Jurassic species, *Brachyphyllum mamillare*, based on some sterile foliage shoots characterised by pinnate branching in one plane; leaves spirally disposed with thick laminæ of triangular, conical or hexagonal form. From that time until the present fossils belonging to this genus have been described by a number of workers: Sternberg, Phillips, Lindley and Hutton, Unger, Murchison, Feistmantel, Carruthers, Schimper, Saporta, Seward, Bancroft, Holden, Sahni, Kendall, and others. Seward in 1919 reviewed the earlier works. By then apart from *Brachyphyllum* a number of species had been described under genera like *Thuites*, *Echinostrobus*, *Mamillaria*, *Pachyphyllum*, *Caulerpites*, *Palæocyparis*, *Palissya*, etc., which were later proved to be synonymous with *Brachyphyllum*. Most of the species described gave no anatomical information. The first important contribution to our knowledge of the anatomical features of *Brachyphyllum* was made by Hollic and Jeffrey (1906). They described *Brachyphyllum macrocarpum* Newb. from the Cretaceous beds of Kreisherville and established its close relationship in some characters with *Araucarioxylon* Kraus. Stopes and Fujii (1910) described the anatomy of *Yezonia vulgaris*, which was later on transferred to *Brachyphyllum*. In 1913 Seward and Bancroft described a few sections of petrified material of *Brachyphyllum eathiense* from Eathie, Scotland and compared the sections with *B. macrocarpum* and *B. vulgaris*. On the basis of the leaf anatomy these authors demonstrated for *Brachyphyllum* a close affinity with the living and fossil Araucarias. The most detailed and systematic work on the English species of *Brachyphyllum* is by Miss Kendall (1947). She too, on the basis of cuticle structure and cones, has shown an Araucarian affinity for this genus. So far she has described six species. In her first paper she described five species: *B. mamillare*, *B. scalbiensis*, *B. cricis*, *B. stemonium*, and *B. desnoyersii* (Brongniart) Saporta. Later in 1949 she described two more species, *B. scotti* and *B. expansum* (Sternberg) Seward, including under *B. expansum* the former species *B. stemonium*.

In India *Brachyphyllum* was first described by Feistmantel (1876, 1877) from Jurassic strata of Cutch and the Rajmahal Hills. Bancroft in 1913 described a few foliage shoots of *Brachyphyllum mamillare* Brongn. from Amrapara on the Bansloi River. Holden (1915) examined the cuticles of some of the Cutch specimens of *Echinostrobus*

expansum which were later referred to by Seward and Sahni (1920) as *Brachyphyllum expansum* Sternb. In 1928 Sahni published an account of four species of *Brachyphyllum*: *B. mamillare* Brongn., *B. rhombicum* (Fst.), *B. Feistmanteli* (Halle), *B. expansum* (Sternb.). In these species he included some of the fossils previously described under such different forms as *Echinostrobus rajmahalense* Fst., *Pachyphyllum peregrinum* Shimp., etc. In one of the specimens of *B. expansum* from Cutch Sahni found the cuticle structure which was somewhat different from the European form, and he described it as *B. expansum* var. *indica*. In 1946 Ganju reported *B. mamillare* from Onthea, a fossil locality in the Rajmahal Hills. Rao in 1947 noted the occurrence of *Brachyphyllum* (probably *B. mamillare* Brongn.) in the cherts of Nipania, another locality in the Rajmahal Hills. He mentions that in these specimens the structural details of internal anatomy are well preserved, but so far he has not published any description of them.

The petrified specimen of *Brachyphyllum* here described was collected by me at Amarjola, a village in the Amrapara District of the Rajmahal Hills in November 1950. There is at this locality an exposure of coarse ferruginous sandstone some 30–40 ft. thick, rich in plant material. A search in the bed showed the presence of *Ptilophyllum*, *Bucklandia*, *Williamsonia Sewardiana*, *Pentoxylon Sahnii*, *Nipaniophyllum*, *Anomozamites*, *Brachyphyllum*, *Coniferocaulon* and a large number of coniferous woods, including one with clearly marked annual rings eccentrically developed around a very narrow pith. A second collection from this locality was made in May 1951.

Material and Technique

The material consists of a rock specimen with fragmentary remains of a foliage shoot. The specimen is fully silicified and, on the whole, the preservation is not very good. From the specimen five sections were prepared: one transverse, one tangential and three radial. The photographs and diagrams were made usually after mounting the slides in liquid paraffin, as it was observed the sections mounted in Canada balsam became too transparent for investigation of the finer anatomical details.

The structure of the epidermis was studied under a strong reflected light. The structure became much more clear when studied under xylol or liquid paraffin. Different stains were also tried and the pieces of leaves mounted in balsam but then the surface characters could not be clearly seen.

Description

The specimen (Pl. VI, Fig. 1) consists of a part of a branched shoot, 2·1 cm in length. The leaves are attached to the surface of the stem by practically the whole of their ventral surface with only a very small portion at the apex left free. The main branch measures 0·4 cm in diameter; the diameter of the two lateral branchlets is about 0·2 cm.

Transverse section.—Pl. VI, Fig. 3, shows the transverse section of the stem with leaves attached. No leaf traces are observed. The

portion between the main axis and leaf-bases has been replaced by silica.

The pith, approximately circular in transverse section, has a diameter of about 0·1 mm. and consists mostly of rather large thin-walled isodiametric cells. They are much crushed due to imperfect preservation. Primary xylem elements are not preserved. The secondary wood is very compact with clearly marked annual rings with a marked eccentric development (Pl. VI, Fig. 4). The size of the rings is variable. The autumn wood is more developed than the spring wood. The cells of the spring wood are thin-walled. The tracheids in both spring and autumn wood are distinctly hexagonal, rarely rectangular and compactly arranged in radial rows. The medullary rays are uniseriate. Resin cells and resin canals are wholly wanting. The phloem and the cambium are not preserved. Traces of cork tissue can be seen here and there. This tissue is very badly crushed, and consists of rectangular cells much elongated tangentially.

Tangential section.—The tangential section (Pl. VI, Fig. 6; Text-Fig. 4) shows that the medullary rays are all uniseriate and 1–4 cells high. Mostly the rays are 2–3 cells high. The highest ray observed is 5-celled. The ray cells are about two times higher than broad. No tangential pits on the tracheids have been seen.

Radial section.—Plate VII, Figs. 7, 8, 9 and Text-Figs. 5, 6 show the radial sections in which the details in the structure of tracheids and medullary rays can be seen. The pitting in the walls of the tracheids consists of uniseriate bordered pits about 5 μ in diameter, the pits are circular and separate. The pore is fairly big, oval and obliquely placed, it measures about 3 μ in length and 2 μ in width. In addition to border pits the tracheids show spiral thickenings. The spirals are close and occur in double series (Pl. VII, Fig. 9). Field pits are not well preserved; they are seen only in one of the medullary ray cells (Text-Fig. 7) which shows 2–4 bordered pits in a field.

Leaves

The leaves are spirally arranged on the stem. They are small and fleshy, tetragonal in shape, and possess a prominent median dorsal keel. The leaf margin is entire, converging towards an obtusely pointed or rounded apex (Text-Figs. 1, 2).

Epidermis and stomata.—The outermost part of the stem and those parts of the leaves which were attached to it, are not preserved, but replaced by silica. Therefore only the abaxial surface could be studied. The epidermal cells are not very regular in shape, and are arranged in longitudinal rows (Pl. VII, Figs. 10, 11). Cells are usually with thickened corners. The margin of the epidermal cells becomes more bright than the centre portion under strong reflected light. Trichomes absent. Stomata numerous, distributed irregularly over the whole of the lower surface, always at some distance from one another. No arrangement in definite rows seen. Individual stomata sunken. Aperture curved. The subsidiary cells are almost invariably five in number; no encircling cells are present.

TEXT-FIGS. 1–7

Fig. 1. *Brachyphyllum* spiroxylum, × 3·2. Fig. 2. Single leaf, × 5. Fig. 3. Part of a leaf, showing the stomata and the epidermal cells, × 340. Fig. 4. Part of secondary xylem in tangential section, showing the uniseriate rays, × 240. Figs. 5–6. Part of secondary xylem in radial section, showing the bordered pits associated with spiral thickening, × 545. Fig. 7. Part of secondary xylem in radial section, showing the bordered pits in 'field', × 535.

A cross-section of the leaves shows the cells of the epidermis to be rectangular, more high than broad. The mesophyll, where preserved, is seen to be formed of elongated cells. The vascular portion is not preserved.

Diagnosis

Woody stem with marked annual rings developed eccentrically around a narrow pith. Autumn wood more developed than spring wood. Tracheids hexagonal. Medullary rays uniseriate, 1–5 cells high. Radial pits on tracheids uniseriate, circular, separate; pore elliptic and oblique. No tangential pitting seen. In addition to border pits the tracheids show spiral thickenings. No wood parenchyma and resin canals present.

Leaves spirally arranged, small and fleshy, with a prominent median dorsal keel. Epidermal cells polygonal and variously shaped with rounded corners. Stomata not arranged in rows and spread all over the abaxial surface; individual stoma sunken. Subsidiary cells five in number; no encircling cells present.

Locality.—Amarjola in the Amrapara District of the Rajmahal Hills, Behar.

Horizon.—Rajmahal stage, Upper Gondwana.

Comparisons and Discussion

As has already been stated, there are few published records of the woods of *Brachyphyllum*. The investigations of Hollick and Jeffrey (1906) on the anatomical features of *Brachyphyllum macrocarpum* Newb. (= *B. crassum*) revealed its close relationship to *Araucarioxylon* and the recent Araucarias. Their conclusions are mainly based on the tracheids of secondary xylem having separate pits in a single row, as well as flattened and alternate bordered pits and medullary rays having numerous pits on the radial walls. They have expressed that it would be unsafe to assume the presence of similar anatomical features in all the leafy branches of *Brachyphyllum*. The description of *B. macrocarpum* was based on a few leafy twigs and some other associated woods without any leaves. So later in 1909 these authors studied the original specimens and created a new genus *Brachyoxylon* for those woods which had no leaves attached and described their specimens under the species *B. notable*. The name *Brachyphyllum macrocarpum* was changed to *B. crassum*. Thus the lack of any organic connection between wood and foliage shoots raises the question whether the wood *B. notable* belongs to *B. crassum* or to those Araucarian woods which have been collected and described from the same locality. *Brachyoxylon* differs from typical Araucarian woods in the frequent occurrence of circular and separate bordered pits. It is in this character only that the stem of the present species of *Brachyphyllum* resembles *Brachyoxylon notable*. Jeffrey (1906) found in transverse sections of *Brachyoxylon* traumatic resin canals. In *Brachyphyllum spiroxylum* resin canals have not been observed. It is unfortunate that the internal anatomy of the leaves of this specimen is not well preserved. Thus

no comparison can definitely be made with the leaves of *B. crassum* which in some respects resembles those of recent Araucarineæ.

An upper Cretaceous plant from Hokkaido, Japan, originally named *Yezonia vulgaris* by Stopes and Fujii and later transferred to *Brachyphyllum* (*B. vulgare*), consists of foliage-shoots, with adpressed spirally disposed leaves. Its cuticle structure is not visible. The secondary xylem have tracheids with uniseriate separate pits and the medullary rays are 1–2 cells in height. Jeffrey (1910) pointed out a close relationship between *Yezonia* and *Brachyoxylon*.

Brachyphyllum eathiense Seward and Bancroft from Upper Jurassic rocks in the North of Scotland has a pith consisting of a few scattered thick-walled cells. The xylem of the crushed stele shows some spiral bands on the innermost tracheids. Pits on the walls of the metaxylem absent. Medullary rays are 1 cell deep. The leaves show a striking resemblance with *B. crassum* and recent Araucarian leaves, in having reticulately pitted isodiametric tracheids. Structure of the stomata and the epidermal cells not known in detail. Stomata with four accessory cells. The Eathie species resembles *B. spiroxylum* only in one character, namely, in having spiral bands in the innermost tracheids; but these tracheids have not been clearly demonstrated.

Holden (1914) described *Brachyoxylon* from the Cretaceous lignites from Cliffwood, New Jersey. This *Brachyoxylon* has been compared with *B. notable* of Hollic and Jeffrey.

From the above description it is evident that there is very little in common between the Brachyoxyla so far described and the present species. The structure of the wood here with spiral thickenings associated with bordered pits on the walls of tracheids, and the absence of resin cells and resin canals are suggestive of a Taxinean wood. Unger (1847) first established the name *Taxoxylon* for fossil woods with no resin canals and with spiral bands in the secondary tracheids. While spiral bands in the tracheids are a common feature of the Taxineæ they also occur outside this family, *e.g.*, in *Pseudotsuga*, *Phyllocladus*, some species of *Abies* and *Larix*. Sometimes spiral bands are also due to some enzyme action; these are not the true spirals. On these accounts various authors have expressed that the presence of spiral bands should not be considered a conclusive evidence of Taxinean affinity.

Taxoxylon scalariforme (Goeppert), a Hungarian wood (originally described by Goeppert as *Taxites scalariformis*), resembles the present stem in having circular, isolated bordered pits on the tracheids along with true spirals, uniseriate medullary rays, no resin canals. Here the height of the medullary rays is from 1 to 10 cells.

The species *T. anglicum* Stopes from the Lower Greensand of England has well marked annual rings with narrow zones of autumn wood; uniseriate medullary rays, 2–10 cells high; bordered pits round, separate, in a single row, with circular pores; rims of Sanio present; spiral thickenings on the walls of the tracheids and 1–6 pits in the field. Seward examined the original slides, and doubted its Taxinean

affinities, as he thought the spiral thickenings were not true bands like those of recent Taxinean woods.

A Japanese Taxinean wood from the Pliestocene of Kanagawā Ken with spiral thickenings on the walls of all tracheids, without resin cells and resin canals, was assigned by Shimakura to *Taxoxylon torreyanum*. In this species transition from early to late wood is gradual; bordered pits fairly small, circular or oval, separate, mostly in one row. *T. torreyanum* differs from *B. spiroxylum* in its medullary rays which are 1–18 cells high and in the occurrence, though rare, of two rows of oppositely arranged pits on radial walls.

In India Mehta in 1941 recovered a few tracheids showing Taxinean sculpturing, from some carbonaceous shales from Singrauli coalfield in Mirzapur District. He compared these pieces with *Spiroxylon* of Walton. The tracheids have spiral thickening bands combined with bordered pits. The pits are elliptical, horizontal and contiguous; in the wider parts of the tracheids pits are either opposite or alternate, when uniseriate either contiguous or separate. Pits in the field, bordered, 6–7 in number. On these characters he referred the microfossils to the genus *Spiroxylon* and gave a new name *S. indicum*. *B. spiroxylum* differs from these microfossils principally in having only uniseriate, circular, separate bordered pits.

Recently Bhardwaj (1952) has given a preliminary report of two new species of *Taxoxylon* from Amarjola and Kālkipāra. One is *T. indicum* characterised by regular growth-rings and eccentric pith, medullary rays uniseriate, 1–6 cells in height; tracheids with uniseriate bordered pits associated with spiral thickening which is in 2 series, field pits 1, rarely 2. In this wood resinous tracheids with resin plates are abundant. The other species, *T. rajmahalense* has irregular growth-rings and eccentric pith; bordered pits nearer the ends, spiral thickening in 2 series. Pits in the field are from 3 to 6, cupressoid or simple. Medullary rays uniseriate and 1–6 cells in height. Except some minute details these woods resemble very much *B. spiroxylum*.

While the wood of the present species shows Taxinean characters, the epidermal structure of the leaves is very similar to that of *Brachyphyllum* and *Pagiophyllum* and other Araucarian leaves. It has been pointed out by various authors that the two genera *Pagiophyllum* and *Brachyphyllum* merge into each other so gradually that in the case of some species it may be difficult to decide to which genus to refer it. They differ only in leaf form, with hardly any difference in their cuticle character. All the four species of *Brachyphyllum* recorded from India are distinguished only on the external features of the leaves. *Brachyphyllum expansum* (Sternb). var. *indica* Sahni is the only Indian species whose cuticular structure has been studied, first by Holden and then by Sahni. It has epidermal cells more or less regular in shape with scattered stomata. There are 4–6 subsidiary cells, with a fine slit-like pore. There is an astomatal area down the centre of the leaf, but this is not a constant feature. There is no such astomatal region in *B. spiroxylum*, and there are only five guard cells. *B. expansum* described by Brick (1925) from Turkestan differs from both these

Indian species in the stomata being placed in definite rows, converging towards the leaf apex. Kendall pointed out that *B. expansum* (Sternb.) from India is different from the English species of *B. expansum* (Sternb.) Seward. The five English species of *Brachyphyllum* described by Kendall resemble the cuticle of *B. spiroxylum* in the distribution of stomata over the whole of the lower surface; in the absence of stomatal rows (except *B. scalbiensis* where there is a well-defined stomatal row); in the sunken nature of an individual stoma and in having a rounded stomatal apparatus with subsidiary cells forming a ring. There are no trichomes. However, the present species differs from them in having less regular epidermal cells and in the absence of definite encircling cells. In external form *B. spiroxylum* is closest to *B. mamillare*. Kendall, on the basis of cuticle characters, has shown a close resemblance of the English *Brachyphyllum* species with *Agathis*, a member of the Araucarineæ. In *Agathis* stomata occur over the lower side only and are distributed in evenly spaced files. The subsidiary cells have papillæ. Cells of the epidermis are short and straight.

We thus see from the above comparisons that while the leaf characters of the present specimen are exactly like those of *Brachyphyllum*, the wood resembles that of the Taxineæ. This fact shows, *i.e.*, that *Taxoxylon* evidently has to be regarded as a form genus even if it is given a very narrow circumscription and based on the characters which are most typically 'Taxinean', *viz.*, the spiral thickenings of the tracheids and the absence of wood parenchyma and of resin canals.

Summary

The present paper records a new species of *Brachyphyllum* (*B. spiroxylum*) collected from Amarjola in the district of Amrapara Rajmahal Hills, India. The type specimen is a portion of silicified foliage shoot, measuring about 2·1 cm. in length and 0·4 cm. in thickness. The secondary wood differs from that in other species of the genus, by the presence of uniseriate bordered pits associated with spiral bands in the tracheids; the pits are circular and separate from each other. In this respect it shows resemblance with some of the fossil and recent members of the Taxineæ. The epidermal structure of the leaves closely resembles the other European and Indian species of *Brachyphyllum*.

Literature Cited

Ball, V. 1877. Geology of the Rajmahal Hills. Mem. Geol. Surv. Ind. 13: Part 2, 1–94 (156–248) with Pls. I–VI and 4 geological maps. Calcutta.

Bancroft, N. 1913. On some Indian Jurassic Gymnosperms. Trans. Linn. Soc. London 2nd. Ser. Botany, 3: Part 2: 69–86, Pls. 7–9 London.

Bhardwaj, D. C. 1952. On some interesting Jurassic woods from Rajmahal Hills, Behar. Proc. 39th Ind. Sci. Cong. pp. 31–32.

Brick, M. J. 1925. Sur quelques conifères jurassiques du Turkestan. Bull. Univ. Asje Centr. Tchkent. 10: 197–203, 2 Pls. (Russ. with French rèsumè) Review in *Bot. Centralblatt* N. F. Bd. VI, 1925–26.

Brongniart, A. 1828. Prodrôme d'une histoire des vegètaux fossiles. VIII: 223, Paris.

FEISTMANTEL, O. 1876. Jurassic (Oolitic) Flora of Kach. Fossil Flora of the Gondwana System, 2: Part I.

————. 1877. Jurassic (Liassic) Flora of the Rajmahal group in the Rajmahal Hills. Ibid. 1: Part 2.

————. 1877. Flora of the Jabalpur Group (Upper Gondwanas) in the Son-Narbada Region. Ibid. 2, Part 2.

FLORIN, R. 1931. Untersuchungen zur Stammesgeschichte der Coniferales und Cordaitales. I. K. Svensk Vet. Akad. Handl. 3: 588, 58 Pls.

————. 1944. Die Koniferen des Oberkarbons un des Unteren Perms. Palæontographica. 85: (B), 7.

GANJU, P. N. 1946. On a collection of Jurassic plants from the Rajmahal Hills, Behar. Jour. Indian bot. Soc., M.O.P. Iyengar Comm. Vol.: pp. 361–374.

HOLDEN, R. 1914. Contributions to the anatomy of Mesozoic Conifers No. 2. Cretaceous Lignites from Cliffwood, New Jersey. Bot. Gaz. 58: No. 2, Chicago.

————. 1915. On the cuticles of some Indian Conifers. Ibid. 60: 215, Chicago.

HOLLICK, A. AND JEFFREY, E. C. 1906. Affinities of certain Cretaceous plant remains commonly referred to the genera *Dammara* and *Brachyphyllum*. Amer. Nat. 40: No. 471: 189–216.

————. 1909. Studies of Cretaceous coniferous remains from Kreischerville, New York. Mem. New York Bot. Gard. 3: 1–138.

KENDALL, N. W. 1947. On the five species of *Brachyphyllum* from the Jurassic of Yorkshire and Wiltshire. Ann. Mag. Nat. Hist. (11) 14: 225–51.

————. 1948. On six species of *Pagiophyllum* from the Jurassic of Yorkshire and Southern England. Ibid. Ser. 12, 1: 73–108.

————. 1949. On a new conifer from the Scottish Lias. Ibid. Ser. 12, 2: 299.

————. 1949. On *Brachyphyllum expansum* (Sternberg) Seward and its cone. Ibid. Ser. 12, 2: 308.

————. 1949. A Jurassic Member of the Araucariaceæ. Ann. Bot. N. S., 13, No. 50.

KNOWLTON, F. H. 1890. A revision of the genus *Araucarioxylon* of Kraus, with compiled description and partial synonomy of the species. Proc. U.S. Nat. Mus. 12: 601–17.

LINDLEY, J. AND HUTTON, W. 1835–36. The fossil flora of Great Britain — III.

MEHTA, K. R. 1942. Palæobotany in India. Report (III). Jour. Indian bot. Soc. 21 (3–4): 218.

————. 1943. Palæobotany in India. Report IV. Ibid. 22 (2–4): 173–74.

RAO, A. R. 1948. Palæobotany in India. Report VI. Ibid. 26: No. 4, 253.

SAHNI, B. 1928. Revisions of Indian Fossil Plants—I. Coniferales (*a*. Impressions and Incrustations). Mem. Geol. Surv. Ind. (*Palæontologia Indica*). New Ser., 11: 1–49.

————. 1931. Revisions of Indian Fossil Plants, Part II. Coniferales (*b*. Petrifactions). Ibid. *Palæontologia Indica*, N. S. 11: 51–124.

SAPORTA, G. 1884. Plantes Jurassiques—Types Proangios permiques et supplément final. Pal. Francaise (2) 4: 547, et las, 74 Pls.

SEWARD, A. C. 1900. The Jurassic Flora — I. Brit. Mus. Cat. Mesozoic Plants, 12: 341, 21 Pls.

————. 1904. The Jurassic Flora — II. Ibid. 15: 192, 13 Pls.

SEWARD, A.C., 1919. Fossil plants. 4: Cambridge.

——— AND BANCROFT, N. 1913. Jurassic plants from Cromarty and Sutherland, Scotland. Trans. Roy. Soc. Edinb. 48: Pt. 4, 867–88.

——— AND SAHNI, B. 1920. Indian Gondwana Plants: A Revision. Mem. Geol. Surv. Ind; Pal. Ind. N. S., 7: Mem. No. 1.

SHIMAKURA, M. 1936. On the fossil wood of *Torreva nucifera* Sieb. et Zucc. from the Pleistocene of Kanagawā Ken, Japan.

STOPES, M. C. 1915. Catalogue of the Mesozoic Plants in British Museum (Nat. Hist.). The Cretaceous Flora Part II. Lower Greensand (Aptian) plants of Britain, London.

——— AND FUJII, K. 1910. Studies on the structure and affinities of Cretaceous Plants. Phil. Trans. Roy. Soc. London. B 210: 1–90.

UNGER, FR. 1849. Einige interessante Pflanzenab drucke aus derk. Petrefactensammlung in Munchen. Bot. Ztg. 9: 345.

———. 1852. Uber einige fossile Pflanzen aus dem lithographischen Schiefer von Solenhofen. *Palæontographica*, Bd. II.

———. 1854. Jurassiche Pflanzeneste. *Palæontographica*. Bd. 4: 39–43.

EXPLANATION OF PLATES

PLATE VI.

Brachyphyllum spiroxylum

FIG. 1. The type specimen from which all the sections were prepared. × 1.

FIG. 2. The same magnified. × 3.

FIG. 3. Transverse section, showing the stem with leaves attached. × 25.

FIG. 4. Transverse section of the stem, showing the well marked growth rings. × 45.

FIG. 5. Part of transverse section, showing the nature of the secondary tracheids. × 250.

FIG. 6. Part of secondary xylem in tangential section, showing the uniseriate rays. × 290.

PLATE VII.

Brachyphyllum spiroxylum

FIG. 7. Part of secondary xylem in radial section showing the bordered pits (*bp.*) associated with spiral thickening (*sb.*). × 610.

FIG. 8. Part of secondary xylem in radial section, showing the bordered pits (*bp.*), associated with spiral bands. × 1220.

FIG. 9. Part of secondary xylem in radial section, showing the spiral thickening (*sb.*). × 690.

FIG. 10. Part of a leaf under reflected light, showing the epidermal cells and the stomata. × 120.

FIG. 11. A portion from the same magnified. × 200.


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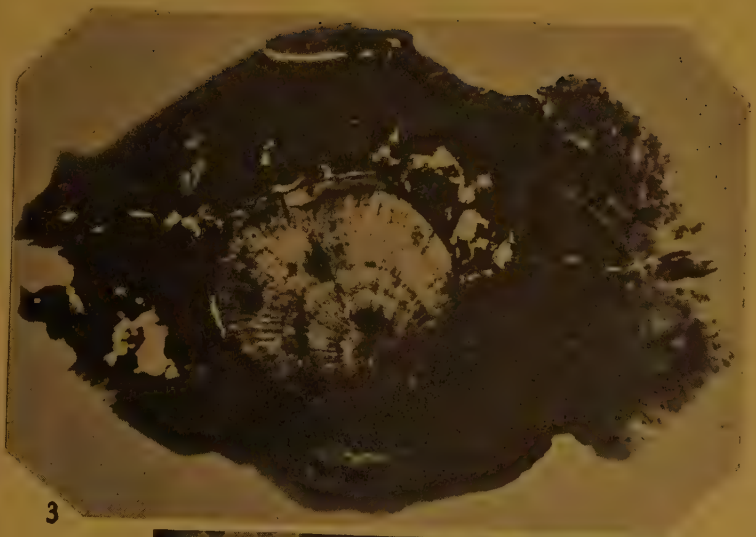
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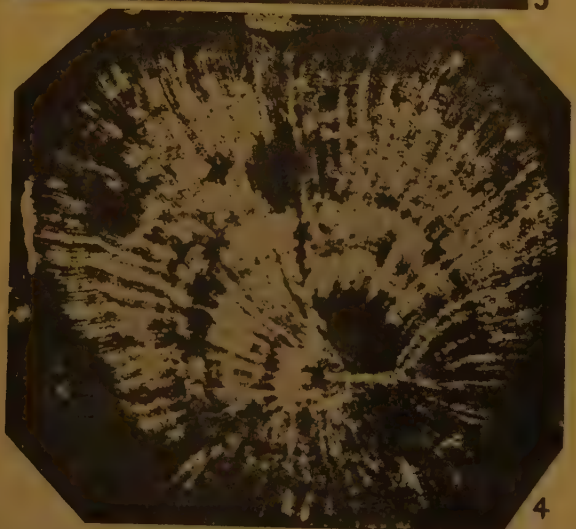
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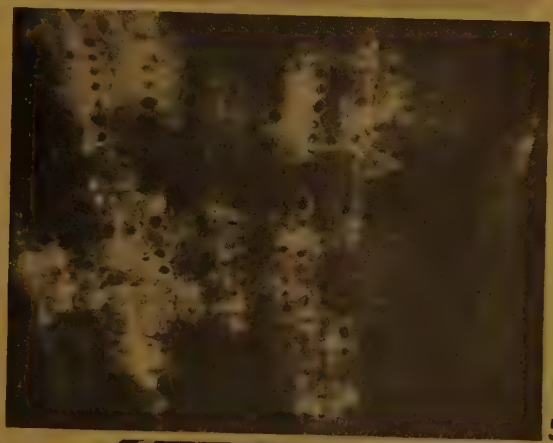
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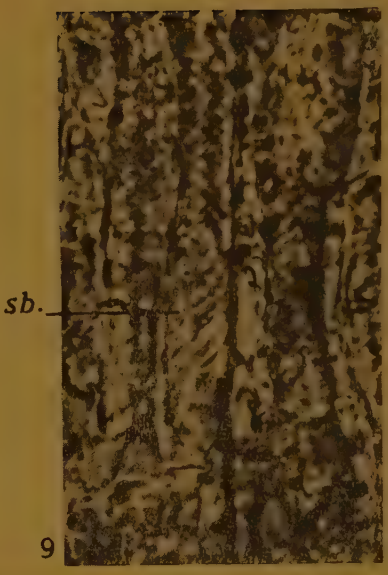

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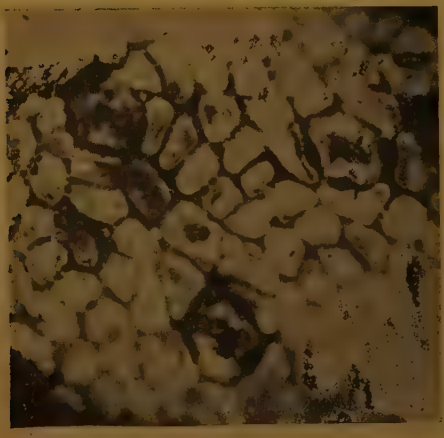

11

M. N. Bose

THE FLORAL ANATOMY OF SOME VERBENACEÆ WITH SPECIAL REFERENCE TO THE GYNŒCIUM

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The pistil in Verbenaceæ is not so constant in its structure as in some of the allied families of the Bicarpellatæ. The carpels are usually two in number, but in some cases there are four, and rarely, even five. The ovary may be 2-, 4-, 8-, or 10-celled, and there is sometimes the formation of secondary septa. Rendle (1936) states that in *Lippia*, *Lantana* and allied genera, the posterior carpel becomes aborted. Warming (1932), on the other hand, states that in some genera, the anterior carpel is aborted. The vascular anatomy of the pistil of a few representatives of the family has been studied in the present investigation with a view to understand more fully the various implications in the reduction of the number of carpels.

Apart from the publications by Junell (1934) and Saunders (1939), the floral anatomy of the Verbenaceæ is unknown. The present paper deals with *Lippia nodiflora* Michaux, *Lantana camara* Linn., *Stachytarpheta indica* Vahl, *Petrea volubulis* Linn., *Duranta plumieri* Jacq., *Citharexylum subserratum* Woodr., *Callicarpa lanata* Linn., *Vitex negundo* Linn., *Tectona grandis* Linn., *Gmelina arborea* Roxb., *Holmskioldia sanguinea* Retz., *Clerodendrum inerme* Gaertn. and *Avicennia officinalis* Linn. Material was collected from the environs of Bombay. The anatomy was studied by following serial transverse sections of the flower buds from the pedicel upwards.

Lippia nodiflora

Calyx small, 2–4 lobed, ultimately 2-valved; corolla tube cylindric, more less 2-lipped; stamens didynamous; ovary 2-celled, with 1 ovule in each cell.

The vascular bundles for the calyx, corolla, and androœcium are given off from the receptacular stele in quick succession. The calyx is supplied by four small bundles. The corolla tube receives the five median bundles of the petals and four vascular bundles for the androœcium (Fig. 1). The behaviour of these is quite normal. There is no indication of a vascular bundle for the missing stamen. Above the androœcium, the stele of the thalamus resolves itself into four prominent bundles. Two of these are the dorsal traces of the two carpels, and the other two are the placental bundles. The posterior dorsal bundle gives out very early a lateral branch on either side (Fig. 1), and these branches divide further to supply the ovary wall.

The anterior dorsal bundle runs upwards without giving off any branches. Sometimes the placental traces also send a small branch into the ovary wall before supplying the ovules. The ovary is unilocular in the basal part, and the two placentas appear clearly to be borne on the inturned margins of the posterior carpel (Fig. 2). Sections clearly show that the inturned structures shown in the figure are not funicles of the ovules, but carpellary margins. The funicle is quite short and arises at the end of the inturned part. The anterior carpel is clearly much reduced in size and extent. As much as about $\frac{7}{8}$ of the surface of the ovary wall is formed by the posterior carpel iteslf. Only the remaining $\frac{1}{8}$ is formed by the anterior carpel. The placental bundles can be regarded as belonging entirely to the posterior carpel, representing its marginal traces. In the basal part of the ovary the two infolded margins are not approximated together, but are separated by a slit-like space which is continuous with the ovule-containing loculus (Fig. 2). At this level, the ovary is therefore unilocular. Higher up, the extreme margins of these inwardly projecting portions of the carpel fuse with the ovary wall opposite the posterior bundle (Fig. 3). Thus the ovary comes to have two distinct ovule-containing cavities. The central septum formed from the carpellary margins has a slit in the middle, and is a double structure. The single anterior carpellary bundle does not divide at all, but simply runs into the style along with the posterior bundle. The other vascular bundles of the ovary wall disappear in the upper part of the ovary. Just towards the extreme tip of the ovary, the septal canal gets reduced in size and becomes lined by deep-staining cells. The canal does not run into the style but the deep-staining cells become continuous with the central transmitting tissue of the style. The two dorsal bundles of the carpels run throughout the length of the style.

Lantana camara

Calyx small, truncate or obscurely toothed; corolla tube cylindric, with 4–5 *spreading lobes; stamens* 4, *didynamous, inserted about the middle of the tube; ovary* 2-*celled, with* 1 *ovule in each cell.*

In this species also, the departure of the vascular bundles for the various floral whorls occurs in quick succession. The calyx receives five vascular bundles. Out of these, four have a direct insertion on the stele while the fifth one arises as a small branch from one of the petal traces in its outward course (Fig. 5). Observation of many buds has shown this peculiar origin to be a constant feature in this species and not merely an abnormality in one or two buds. The corolla tube receives the five midrib traces of the petals and four bundles for the stamens (Fig. 6). The subsequent behaviour of all these is normal. The general construction of the ovary and the vascular supply conforms in essentials to the *Lippia* type (Figs. 7-9), but there are some important differences. The median bundle of the anterior carpel, although comparatively smaller than the posterior one, bears lateral branches that run in the ovary wall. The two placental strands extend a little way up in the septum after supplying the ovules and then disappear. The lateral traces of the ovary wall

extend into the basal portion of the style and then disappear. All other features are exactly as in *Lippia*.

Stachytarpheta indica

Calyx elongate, narrowly cylindric, shortly 4–5-*toothed; corolla tube cylindric, with* 5 *spreading lobes; perfect stamens* 2, *and* 2 *minute staminodes, the latter sometimes absent; ovary* 2-*celled, with* 1 *ovule in each cell.*

Here also the vascular bundles of the different whorls arise in quick succession, and the vascular supply to the calyx can be traced to three bundles which arise from the receptacular stele. Two of these divide each into three branches, the median one of which forks again into two radially placed bundles (Figs. 10 and 11). The outer one of these latter two runs into the calyx and the inner one is the midrib bundle of a petal. The midrib bundles of the three other petals arise directly from the stele. The third vascular bundle of the calyx, which is posterior in position, divides into three. These branches supply the calyx only. The two lateral branches of this posterior bundle fuse for a time with a corolla strand in their outward course, then separate and supply the calyx (Fig. 10). This at first creates the impression that the corolla trace is sending a branch into the calyx, but close observation has shown that the calyx bundle is only touching the outer margin of the corolla strand and separating immediately. The calyx tube thus contains at its base nine vascular bundles, but one or two of these may divide once again. There are four vascular bundles given out for the androecium—two for the functional stamens and two for the staminodes (Fig. 11).

Above the insertion of the corolla tube, the stele of the floral axis resolves itself into two large "placento-parietal"* traces and two small dorsal traces of the two carpels (Fig. 12). Each placento-parietal bundle gives out on its side a number of branches into the ovary wall, mainly towards the posterior side and then the bundle supplies an ovule (Figs. 13 and 14). The dorsal trace of the anterior carpel bears one or two small lateral branches close to it. The construction and vascular anatomy of the gynæcium is as in *Lippia* and *Lantana* (Figs. 15 and 16). The cavity in the septum is specially large and is lined by an "epithelial layer". This canal extends prominently even above the ovule-bearing region. In the basal part of the style the lateral vascular bundles of the ovary wall on each side fuse together and fade, leaving only the two midrib bundles of the carpels which run throughout the length of the style. In the lower half, the style is hollow, its canal being continuous with the septal canal, but towards the apex the canal gets completely filled up by the epithelial layer, so that the style becomes solid, with a central transmitting tissue.

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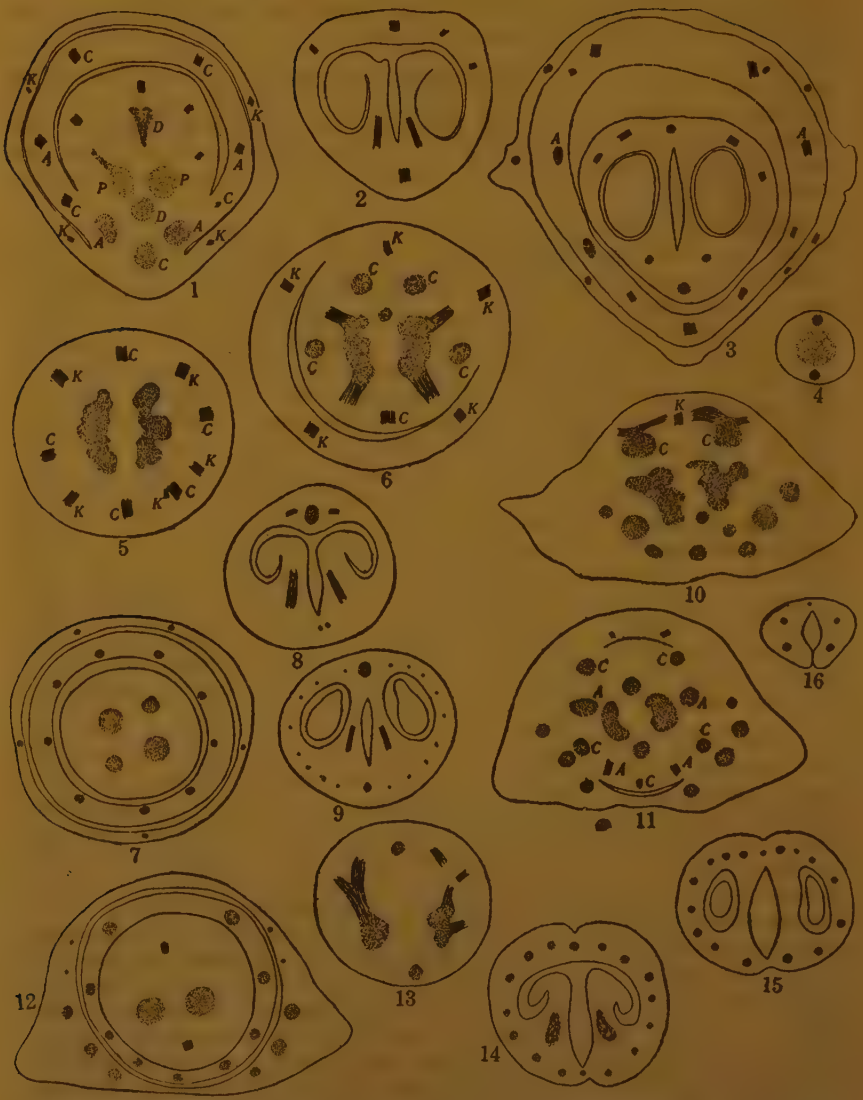
* A term coined only for convenience in description. It is here applied for a bundle which divides to supply the placentas as well as part of the ovary wall. The term 'parietal' as used here has no significance except to indicate the bundles of the ovary wall other than the dorsal traces.



FIGS. 1–16; Figs. 1–4. *Lippia nodiflora*

Fig. 1. The posterior dorsal bundle has already given out a lateral branch on either side. One of the placental bundles can be seen to be sending a branch into the ovary wall. Fig. 2. Section of ovary showing the inturned margins of the posterior carpel, and appearing almost like funicles of anatropous ovules. The actual funicles here are quite short. Fig. 3. Bilocular condition of ovary

caused by inwardly projecting carpellary margins of posterior carpel fusing with ovary wall. Fig. 4. Section through style showing the two midribs of the carpels and central transmitting tissue. Figs. 5–9. *Lantana camara*. Figs. 10 to 16. *Stachytarpheta indica*. Fig. 10. The tangential rows of calyx traces with 3 bundles in each can be seen. Those of the dorsal side are obliquely cut, and two petal traces are in contact with two of these. Fig. 11. Showing the division of the middle bundle in the two antero-lateral groups to form an inner petal trace. For other figures, explanation is in the text.

PETREA VOLUBILIS

Calyx cup-like, with 5 lobes; corolla salver-shaped, 5-lobed; stamens 4, didynamous; ovary 2-celled.

The calyx receives the five midrib bundles of the sepals, each with a marginal vein on either side, so that altogether there are fifteen vascular bundles (Figs. 17 and 18). The origin of these, however, is rather irregular. Some median bundles arise directly from the stele, while in other cases a marginal bundle and a median one arise by the division of a common trace. This common trace might also be fused at the base with a midrib bundle of a petal. This is a very common condition. Two adjacent marginal bundles of the calyx also sometimes arise by bifurcation of a common bundle. Each marginal trace divides higher up into three branches.

The corolla tube receives the five midrib bundles of the petals and four vascular bundles for the stamens (Figs. 17 and 18). The vascular bundles of the petal may be inserted directly on the receptacular stele, or they may be fused with the marginal strands of the calyx.

At the place where the fifth vascular bundle of the androecium is missing, the corolla bears a non-vascular staminode (Fig. 21). At about the level of insertion of the stamens, each of the petal traces bears a lateral branch on either side, and still higher up, there is another branching of the vascular bundles. The xylem of the vascular bundles of the stamens is sometimes semicircular in section, but usually it is separated into two, rarely more, parts.

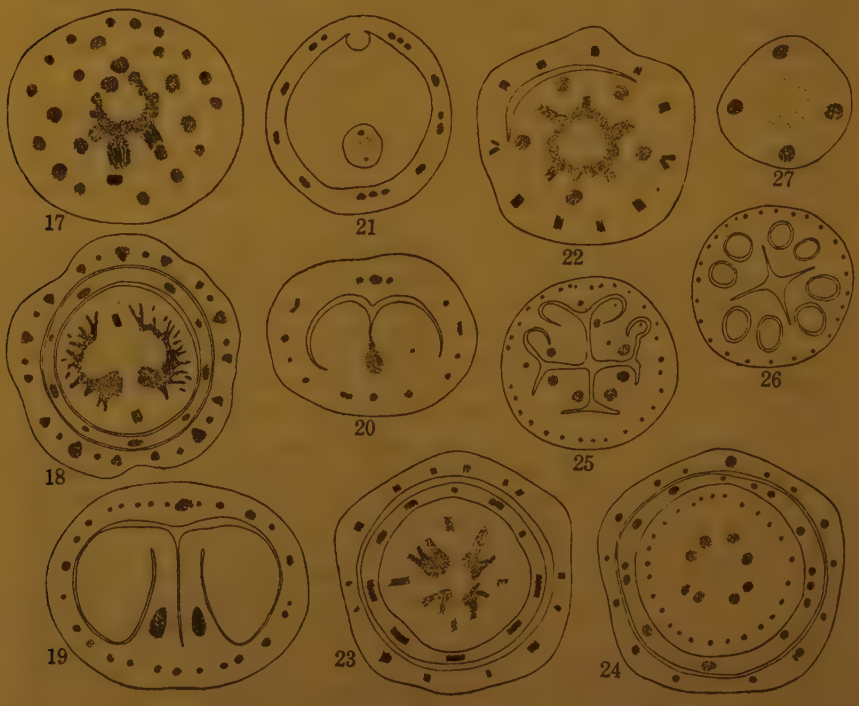
At the base of the ovary the stele breaks up into two midrib bundles of the carpels, and two large "placento-parietal" bundles. Each placento-parietal strand gives out towards the posterior side and to the lateral side a number of small branches to the ovary wall (Fig. 18). The midrib bundles of the anterior carpel bear two or three small laterals on either side close to it. Thus a very great portion of the ovary wall receives vascular supply from the two placento-parietal bundles. The midrib bundles of the posterior carpel also bears a few side veins. After sending branches to the ovary wall, the two placental strands are left and they supply the ovules (Fig. 19). The vascular anatomy of the pistil agrees with the previous species except for the following differences. The canal between the two placentiferous portions is extremely narrow, and the two epithelial layers almost touch each other (Fig. 19). This deep-staining epithelial tissue is directly continuous with the central conducting tissue of the style (Fig. 20). A large part of the placental bundle runs into the ovule,

but a small portion travels vertically upwards for a good distance and then fades away. This fading vascular branch is not connected either directly or indirectly with the transmitting tissue of the style. The style is of the solid type.

Duranta plumieri

Calyx small, 5-toothed; corolla tube cylindric, with 5 lobes; stamens 4; didynamous; ovary 4-celled.

The general method of vascular supply to the calyx in *Duranta* is by five unbranched midrib bundles of the sepals and five commissural traces which bifurcate in their outward course. The five petal traces are fused at the base with the commissural bundles of the calyx. There are five vascular bundles for the andrœcium and they arise directly from the stele (Figs. 22 and 23). One of these five is small and it supplies a small staminode which is clearly seen in buds but usually disappears in fully open flowers. Even below the level of insertion of the stamens, each of the petal traces divides into



Figs. 17–27. Figs. 17–21. *Petrea volubilis*

Fig. 17. Shows vascular bundles of calyx and corolla in distinct rings. Fig. 18. Showing the origin of some ovary wall bundles from the "placento-parietal" bundles. Fig. 22–27. *Daranta plumieri.* Fig. 23. Shows the four dorsal bundles and the four placento-parietal bundles of the ovary, which supply the ovary wall and form placental bundles.

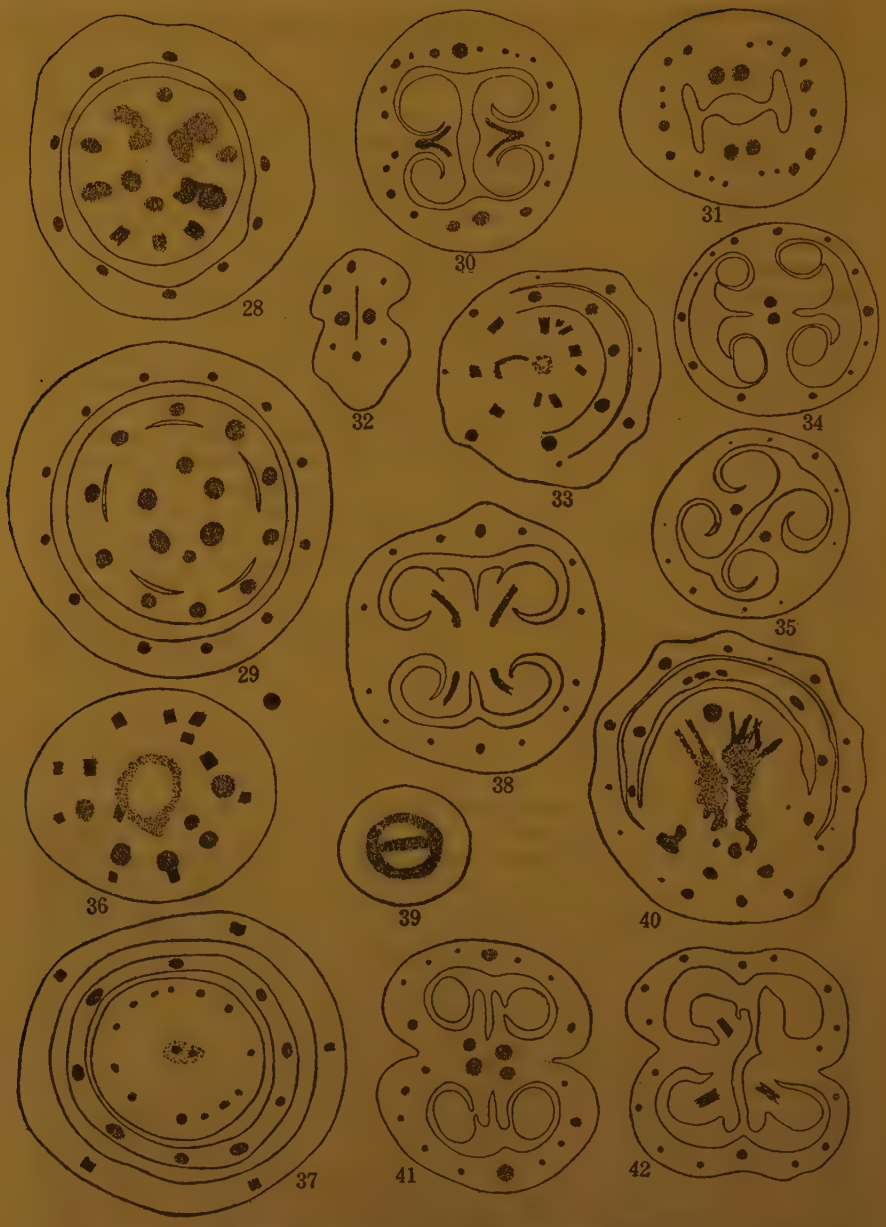
three. In the connective the staminal trace sends a small downward branch towards each anther lobe.

Above the insertion of the corolla, the stele breaks up into four small dorsal bundles of the four carpels, and alternating with these, four large bilobed placento-parietal strands with the lobes towards the outside. From each lobe of the placento-parietal bundle is given off a repeatedly branched bundle towards the outside. All these branches supply the ovary wall (Fig. 23). The two main lobes of each strand separate out, and the eight bundles thus derived are the placental traces (Fig. 24). The four dorsal bundles of the four carpels do not now differ in appearance from the other ovary wall traces. Usually each dorsal trace gives out a lateral branch in its outward course. At the base of the ovary are seen four parietal placentas extending towards the centre (Fig. 25) and each placenta represents the fused margins of two adjacent carpels. The placentas appear peltate in section with the ovules on the margin. Alternating with the placentas the ovary wall develops a triangular inward projection (Fig. 25). Into these four projections the corresponding dorsal bundles send branches, but these fade out. Higher up, these inwardly projecting portions of the wall fuse with the enlarged ends of the placentas, so that eight ovule-containing loculi are formed (Fig. 26). In the centre, a small canal is enclosed, and it is lined by a deep staining tissue. All the vascular bundles except the four dorsal traces disappear towards the apex of the ovary. These four dorsal bundles run throughout the length of the style (Fig. 27) which is of the solid type.

Citharexylum subserratum

Calyx small, 5-toothed; corolla tube with 5 short spreading lobes; stamens 4; staminode 1; ovary 4-celled; ovule 1 in each cell.

At the base of the thalamus are four vascular bundles of varying sizes. These increase in size as well as in number in the thalamus but the vascular bundles remain separate and do not form a complete ring. From this stele, ten vascular bundles are given off to the calyx (Fig. 28). These may bear a few branches. Above the origin of the vascular supply to the calyx the stele resolves itself into four large and five comparatively small alternating bundles. One of the small strands sends two branches outwards. Three of the larger strands divide each into an outer and an inner trace, while the fourth large bundle divides into an outer and two inner traces. The six outer traces thus derived, along with the remaining four original small traces, run into the corolla tube (Fig. 28). Of these ten, five are the midrib bundles of the petals, and the remaining alternating five supply the four stamens and the staminode. This leaves six bundles as an inner ring (Fig. 29). Out of these, two facing each other are small. They are the median bundles of the two carpels. The other four larger bundles are the marginal bundles of the carpels. All these six, however, send branches into the ovary wall. The four marginal bundles fuse in pairs and function as placental bundles (Fig. 30). The ovary is uniolcular only at the base, but higher up septa, appearing as outgrowths from the two parietal placentas, join the ovary wall



Figs. 28–42. Figs. 28–32. *Citharexylum subserratum*

Figs. 28. Shows in the floral axis an outer ring of ten bundles which enter the corolla tube. Fig. 32. is a section passing through the apical portion of the ovary. Figs. 33–35. *Callicarpa lanata*. Fig. 33 shows the 8 calyx strands in outer ring, 4 of the petals and 4 of the stamens as a second ring ; a third ring of ovary wall bundles, and in the centre, the placental supply. Figs. 36–38. *Vitex negundo*. Fig. 39 to 42. *Holmskioldia sanguinea*. Fig. 40. Shows the division of a petal bundle into three.

opposite the median bundles of the carpels. Thus four loculi in the upper portion of the ovary are formed, each enclosing an ovule. The placental bundles are not used up in supplying the ovules, but they extend upwards to the basal part of the style. They often bifurcate into two (Fig. 31) and bend in the direction of the corresponding dorsal bundle before fading out. It is also seen occasionally that they fuse with the lateral bundles. Only the two dorsal bundles of the carpels run into the style. The centre of the style is occupied by a conducting tissue.

Callicarpa lanata

Calyx very small, truncate or minutely 4*-lobed; corolla tube short, with* 4 *spreading lobes; stamens* 4, *equal; ovary imperfectly* 2*-celled; ovules* 2 *in each cell.*

The vascular supply to the calyx is made up of eight strands, four midrib bundles of the sepals and four commissural bundles (Fig. 33). The four vascular bundles of the petals and the four for the androœcium arise almost simultaneously with the eight sepal traces so that the vascular bundles on the same radii appear to have a common origin. In the corolla tube the vascular bundles for the stamens are of a larger size than the corolla traces. The receptacular stele then gives out two dorsal bundles of the carpels and a number of strands for the ovary wall. The dorsal bundles bear median laterals. The departure of these traces leaves behind in the centre a single placental bundle which higher up divides into two. In the lower part, the ovary is completely bilocular (Fig. 34). In the upper ovule-bearing part, however, the two loculi communicate by a canal through the septum (Fig. 35). The ovules clearly arise on the inturned margins of the carpels. Each part of the septum receives one placental bundle. At the apex of the ovary the lateral vascular bundles of each carpel fuse with the dorsal strand. Only the two dorsal bundles of the carpels are continued into the style, which is of the solid type. The central transmitting tissue of the style increases gradually towards the tip of the style and in the stigma it expands out to form the receptive surface.

Vitex negundo

Calyx truncate or shortly 5*-toothed; corolla* 2*-lipped; limb* 5*-lobed; stamens* 4, *didynamous; ovary* 2–4*-celled; ovules* 4.

The calyx receives the five midrib traces and five commissural bundles, but all these ten do not have a direct origin from the stele of the thalamus. In the flowers observed by the author, eight vascular bundles had a direct origin from the stele, of which two bifurcated, and thus gave rise to ten strands. The corolla tube receives the five midrib bundles of the petals and four vascular bundles for the stamens. Eight out of these nine are fused at their base with the eight sepal traces. The ninth vascular bundle—a staminal trace—has a direct origin from the stele (Fig. 36). About the middle of the length of the anther, the staminal bundle gives off almost horizontally, a very short lateral trace towards the anther lobes on either side.

Almost immediately after the departure of the petal and staminal traces, the receptacular stele gives off 9–11 strands, some of which divide once and increase the number to 14–16 (Fig. 37). The central stele now organises itself as two closely approximated placental bundles with a concentric structure. Near the ovule-bearing part, these two central bundles fuse into a single strand, but the two xylem groups remain distinct (Fig. 37). Out of the peripherally placed 14–16 bundles, two opposite ones are the midrib traces of the carpels, while the others supply the wall. The ovary is bilocular at the base and also in the ovuliferous part (Fig. 38). The central vascular bundle breaks up into two, each with a single xylem group. The xylem of each bundle again divides into two groups, and these supply the placentas of the two different carpels. The placental bundles are exhausted in supplying the ovules. Above the ovule-bearing zone, the two loculi communicate with each other through a canal in the septum for a short distance. The style is solid and contains the central conducting tissue and the two midrib bundles of the carpels.

Holmskioldia sanguinea

Calyx orbicular; corolla 2-lipped, 5-lobed; stamens 4, didynamous; ovary 4-celled, with 1 ovule in each cell.

The vascular tissue in the pedicel is in the form of a complete cylinder. Just below the base of the thalamus it extends inwards into the pith from two opposite sides and by a union of these two extensions, a bridge of vascular tissue is formed across the pith for a short distance (Fig. 39). Higher up this bridge breaks up first into three, and then into more branches, which are found scattered irregularly in the centre of the vascular cylinder of the thalamus. Subsequently these branches merge again with the main vascular cylinder.

The vascular supply to the calyx arises as nine (or ten) bundles and each of these divides into three. The adjoining laterals fuse in most cases. Other lateral branches are developed by some of the vascular bundles, bringing the total to 24–26 strands. The corolla tube receives the five midrib bundles of the petals, and four bundles for the androecium (Fig. 40). Each of the five petal traces divides into three much below the level of insertion of the stamens. Some more branches are given out near the level of insertion of the stamens. Above the origin of the corolla and stamen traces, the stele gives out the two dorsal bundles of the carpels, and two larger plates of vascular tissue. The latter gives out numerous traces (Fig. 40) to the ovary wall and form two placental traces which in the basal portion are sometimes more or less fused together. Each of the two placental bundles divides into two, so that four placental bundles are organised (Fig. 41). The ovary is bicarpellary and bilocular at the base and the placental bundles appear clearly as the marginal bundles of the carpels. Above the ovule-bearing region, an extremely narrow channel links up the two loculi (Fig. 42). The placental strands are completely exhausted in supplying the ovules. The style is of the solid type. The midrib bundles of the carpels run into it on two sides of the central transmitting tissue.

Clerodendrum inerme

Calyx 5-toothed; corolla tube with 5 spreading lobes; stamens 4; ovary imperfectly 4-celled, with 1 ovule in each loculus.

The vascular supply of the calyx arises as ten vascular bundles, which branch and unite again irregularly, so that ultimately the calyx comes to contain about 25 vascular bundles. The vascular bundles for the corolla arise as five traces. Immediately afterwards, four larger bundles are given off for the andrœcium. All these nine vascular bundles enter the corolla tube. The petal traces may branch early. (Figs. 43 and 44). The stele then gives out the midrib bundles of the two carpels, and also a number of lateral bundles that supply the ovary wall (Fig. 44), leaving in the centre, two placental bundles. Even near the base of the ovary, the placental bundles give out a few branches into the ovary wall. The ovary is bilocular. Each of the two placental bundles divides into two, thus forming four placental strands (Fig. 45). These placental traces appear clearly as belonging to the margins of the carpels which are folded inwards. Opposite the dorsal strands of the carpels the ovary wall projects inwards. In the ovule-bearing zone the carpellary margins enclose between themselves a space in the centre of the ovary. Although the placental bundles supply mainly the ovules, they give out a few small branches into the carpellary margins also, as can be expected if the septum is formed through an infolding of the carpels. Above the ovule-bearing zone, the two loculi communicate with each other by a very narrow slit. As the loculi come to a close, the marginal bundles of the carpels (those given out by the placental strands) move towards the dorsal bundles and disappear. Only the two dorsal strands run into the style. The style is hollow in the basal portion. The stylar canal is in direct continuation of the space enclosed in the centre of the ovary by the inwardly curled carpellary margins. Higher up, the style becomes solid for some distance, but it is hollow again near the apex.

Tectona grandis

Calyx 5–6-lobed; corolla tube with 5–6 spreading lobes; stamens 5–6, equal; ovary 4-celled, with 1 ovule in each cell.

The flowers of *Tectona grandis* are either pentamerous or hexamerous, but all the flower buds sectioned happened to be hexamerous. The vascular supply to the calyx is on the usual 6+6 plan (six median bundles and six commissurals). In addition to these twelve bundles, other vascular bundles arise alternating with these twelve. Each of these latter bifurcates. The resulting small branches also run into the calyx (Figs. 46 and 47). Immediately above the origin of the calyx traces, the stele gives off the six petal midribs and six staminal traces, all of which enter the corolla tube. The vascular bundles of the stamens are slightly larger in size than those of the petals. Near the insertion of the filaments, the midrib bundles of the petals bear a lateral branch on either side. In the connective region, the vascular bundle of the stamen sends a downward trace into each anther lobe. Just before the fading out of the staminal trace at the apex, it shows a slight bifurcation.

Immediately after the origin of the bundles for the corolla tube, the stele of the thalamus gives out 20–25 small traces towards the outside for the ovary wall, and forms towards the centre two large and two small bundles (Fig. 48). Out of the 20–25 bundles travelling towards the periphery, two opposite ones are the midrib

Figs. 43–54. Figs. 43–45. *Clerodendrum inerme*

Fig. 43. Shows an outer ring of calyx traces and inner ring of five petal traces. Figs. 46 to 49. *Tectona grandis*. Figs. 50–54. *Gmelina arborea*. Explanation in the text.

bundles of the carpels. These stand out prominently in the upper part of the ovary. The ovary is 4-locular. The four vascular bundles in the centre (two small and two large) fuse incompletely for a short distance. Higher up this fusion product divides into four branches

and these supply the four ovules (Fig. 49). These four ovule-traces are almost entirely made up of the two large bundles above mentioned. The small bundles which partially unite with the larger ones clearly fade out at this level without contributing towards the formation of the ovule traces. These two small bundles are opposite the two dorsal bundles of the carpels which run into the style.

Many bundles of the ovary wall run into the basal part of the style, where they gradually fuse with the two dorsal bundles. In the upper portion of the style, only the two dorsal strands continue to run. The style contains a narrow hollow canal in the basal half, but higher up its place is occupied by a solid transmitting tissue.

GMELINA ARBOREA

Calyx 4–5-*toothed or sub-entire; corolla* 2-*lipped; stamens* 4; *ovary* 4-*celled, with* 1 *ovule in each cell.*

The pedicel contains a ring of 8–10 bundles, but in the thalamus, the number of the bundles increases first to about 15 and higher up to 20–25. The vascular ring widens out and vascular branches are given off into the medullary region. The medullary vascular tissue shows two large and two small bundles prominently. These are the staminal traces. They become of equal size higher up. The medullary vascular tissue standing apart from the four prominent bundles resolves itself then into a number of bundles arranged like 8 (Fig. 50). These traces supply the pistil. From the outer ring of about 25 bundles, five equidistant bundles travel inwards (Fig. 51). These are the midrib bundles of the petals. These enter the corolla tube along with the four staminal traces. Each of the corolla strands sooner or later divides into three. The numerous vascular bundles forming the outer ring now supply the calyx.

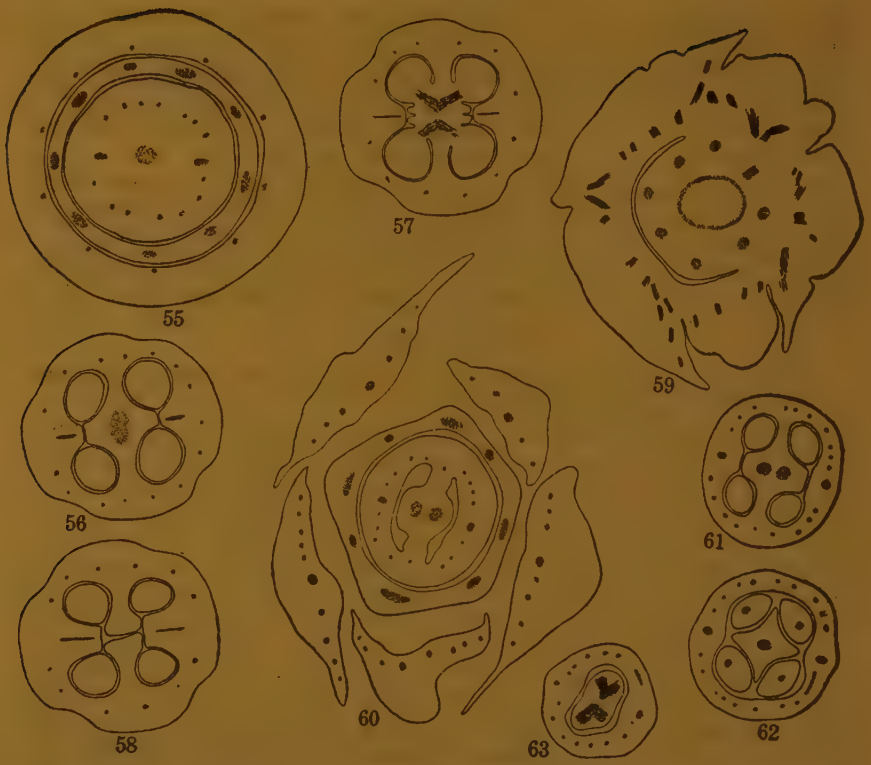
The various bundles arranged as figure 8 in the centre resolve themselves into a ring of 60–70 equal bundles for the ovary wall, and four small placental bundles in the centre (Figs. 52 and 53). The four placental bundles stand opposite the four loculi of the ovary and supply the ovules. They are not used up, however, in supplying them (Fig. 54). Higher up they fuse in pairs, and the two traces extend for some distance upwards. At the apex of the ovary, as the base of style is approached, the number of the vascular bundles in the ovary wall gradually decreases by fusions. Only the two dorsal bundles of the carpels run through the length of the style, which is of the solid type.

In the region of the connective the staminal traces give off short branches into the anther lobes.

PREMNA INTEGRIFOLIA

Calyx small, cup-shaped; corolla 2-*lipped; stamens* 4; *ovary* 2–4-*celled; ovules* 4.

At the base of the thalamus there is a complete ring of vascular tissue. The vascular supply to the calyx consists of five median and five commissural bundles. The latter branch, where as the midrib



FIGS. 55–63. Figs. 55–58. *Premna integrifolia*; Figs. 59–63. *Avicennia officinalis*.

bundles are mostly unbranched. There are five midrib bundles of the petals. They are fused at the place of origin and for some short distance upwards, with the commissural bundles of the calyx. There are four vascular traces for the four stamens. They arise directly from the stele, alternating in position with the corolla strands. Immediately above the origin of the staminal traces, the stele breaks up into two dorsal bundles of the carpels and two larger "placento-parietal" strands. The two placento-parietal bundles fuse more or less in the centre. The resultant strand gives rise by division to about eight bundles for the ovary wall, and a placental bundle in the centre (Fig. 55). The ovary is imperfectly 4-locular, but sections clearly show that this is derived from a bilocular condition through projections of the main septum towards the ovary wall opposite the dorsal bundles of the carpels (Figs. 56 and 57). At this point the ovary wall also shows a slight inward projection and the dorsal bundles extend into it. The placental bundle divides first into two and each again bifurcates, the branches supplying the four ovules. Higher up the ovary is bilocular because the secondary projections of the septum do not touch the ovary wall. Still higher up the ovary wall projects prominently inwards

opposite to the dorsal bundles, but in the centre the septum ceases to be continuous, showing the carpellary margins clearly (Fig. 58). The style is solid, containing the two dorsal bundles of the carpels and a central transmitting tissue.

Avicennia officinalis

Calyx short, 5-partite; corolla tube short, with 4 unequal lobes; stamens 4; ovary imperfectly 4-celled, with a 4-winged central axis; ovules 4, pendulous, between the axial wings.

The pedicel contains a ring of vascular bundles. The calyx is supplied by five median and five commissural bundles, all of which branch to some extent. The commissural bundles supply adjacent sepal margins. The corolla tube receives four petal midribs and four bundles for the stamens. They are equidistant from one another and alternating (Fig. 59). The petal bundles branch in the corolla tube. About the level of emergence of the traces for the corolla tube, the thalamus contains a complete vascular ring which sends four placental traces towards the centre. The ring then breaks up into a number of bundles for the ovary wall. Two opposite ones of these are the dorsal bundles of the carpels. Of the four placental bundles, the two belonging to each carpel fuse early so that only two placental bundles are derived (Fig. 60). The ovary is bilocular at the base (Fig. 61). Higher up it becomes partially 4-celled by outward projections of the septum towards the ovary wall opposite the dorsal bundles of the carpels. Still higher up the septum separates itself off from the ovary wall on all sides and appears like a 4-winged central axis (Fig. 62). The two placental bundles fuse into a single trace. This placental bundle divides into four branches and they run into the four pendulous ovules that arise at the top of the winged septum (Fig. 63). Only the two dorsal bundles run throughout the style. The style contains a narrow slit-like canal lined by deep-staining transmitting tissue.

Discussion

The vascular supply to the calyx in the investigated members of the family shows a good deal of variation. In *Lantana*, there are five vascular bundles, of which one is united at the base with a petal strand. Normally, sepal and petal midribs should alternate, but in this species every flower sectioned showed the highly peculiar feature of cohesion in one of the five bundles. In *Lippia*, there are only four sepals and they are supplied by four vascular bundles. In *Stachytarpheta*, all the vascular bundles of the calyx are traceable to only three strands, and there is also the fusion of two vascular bundles of the petals with the calyx traces. The vascular supply in *Petrea* is highly irregular and in *Duranta* it consists of five median and five commissural bundles. In *Citharexylum*, the calyx is supplied by ten bundles, of which five should be regarded as the midrib bundles and the other five, commissural bundles. *Lantana*, *Lippia*, *Stachytarpheta*, *Cithrexylum*, *Petrea* and *Duranta* are all included under the tribe *Verbeneæ* by Bentham and Hooker (1883). Taking into consideration

the vascular supply of the calyx alone, that of *Duranta* is simplest. Some members of the family have a calyx of five members, while others have only four. Thus, there is a reduction in the number of sepals in the family. From the 5-membered calyx, as well as from its vascular supply, *Duranta* appears to be comparatively primitive. Although *Petrea* has a 5-membered calyx each with a median and two dorsal veins, the irregularity in the origin of these indicates that the species is in an unstable condition, apparently heading towards a reduction in the vascular supply of the calyx. *Vitex* resembles *Duranta* very much in its calyx supply. *Holmskioldia, Clerodendrum* and *Stachytarpheta* represent simple modifications of the typical plan. The calyx of *Callicarpa* is supplied with four median and four commissural bundles, while that of *Lippia* receives the four median bundles only. Thus the calyx shows various stages in reduction in the number of sepals as well as in its vascular supply.

In *Tectona grandis*, the calyx receives not only the six midrib and the six commissural traces, but also a number of additional traces from the stele. The vascular supply to the calyx of *Premna* and *Avicennia* is on the typical 5 + 5 plan but in *Gmelina* the calyx receives a large number of bundles.

The vascular supply of the corolla is remarkably uniform, as is also the case in the related families *Acanthaceæ and Bignoniaceæ* studied by the author (unpublished observations). Each petal has a midrib strand which gives out a lateral branch on either side at about the level of insertion of the stamens, or sometimes even at a lower level. In many genera, these are fused at the base with the vascular traces of the calyx. In *Vitex*, some of the vascular bundles of the stamens are adnate for some distance even with the sepal traces.

Duranta and *Citharexylum* have four vascular bundles for the functional stamens and one for the staminode. *Petrea* has four functional stamens and a staminode, but the latter is not provided with a vascular bundle. It is thus a case where the vascular supply has disappeared before the organ that it supplied. In *Lantana*, *Callicarpa*, *Vitex*, *Holmskioldia*, *Clerodendrum*, *Gmelina*, *Premna* and *Avicennia*, there are four functional stamens and four vascular bundles supplying them. There is no trace of the fifth strand. The hexamerous flowers of *Tectona* have six vascular bundles for the six stamens. *Stachytarpheta* has two staminodes, each supplied by a vascular bundle. Thus on the basis of the structure of the calyx as well as that of the androecium, *Duranta* shows a primitive state in the tribe Verbeneæ, while *Stachytarpheta* shows much reduction. Similarly in the tribe Viticeæ, *Tectona* shows obvious primitive features. All the stamens are fertile and there are no special adnations of vascular bundles of different sets.

The fact that each anther lobe in *Duranta*, *Vitex* and *Tectona*, which show comparatively primitive features in the vascular anatomy of the calyx and pistil, receives a small trace as a branch from the staminal bundle running in the connective, is noteworthy.

The vascular anatomy of the gynæcium of *Duranta* proves beyond doubt that there are four carpels, each having two ovules on parietal placentas. The base of the gynæcium clearly shows four dorsal strands of the carpels and four large placental bundles, which send prominent branches into the ovary wall. The view that there are four carpels present is confirmed by the fact that four dorsal traces run in the style as well. The 8-locular nature of the ovary is obtained by the inwardly projecting margins of carpels and the inward projections of the ovary wall opposite the dorsal bundles. Taking for granted that a large number of carpels is a primitive character, *Duranta* shows primitiveness not only in the structure of its calyx and androœcium but also in the gynæcium. All the four carpels of *Duranta* are fertile, *i.e.*, ovule-bearing. *Citheraxylum*, belonging to the same tribe, has only two carpels. The ovary, however, although unilocular at the base and showing parietal placentation, becomes 4-locular by extensions of the placentas on either side towards the dorsal bundle of each carpel.

In *Callicarpa*, there are only two carpels present. Both of them are equally developed and ovule-bearing. At the base of the ovary there is a single placental bundle which becomes divided into two higher up. In *Vitex*, *Holmskioldia*, and *Clerodendrum* also there are two fertile carpels, but in these three genera, in the region of supply of the ovules, four placental bundles are obtained by division. Assuming that a large number of placental bundles indicates a more primitive condition, *Callicarpa* can be regarded as more advanced than these genera. *Tectona* has only two carpels and both of them are fertile. There are two large placental bundles that supply the ovules. Apart from these two large placental bundles, this axile region also contains two small traces lying on the same radius as the dorsal bundles of the carpels. These fade out without supplying the ovules. Although no proof or satisfactory explanation for this can be given at this moment, it is likely that this feature might have some relation with an ancestral 4-carpellary condition. The ovaries of *Gmelina*, *Premna* and *Avicennia* are also composed of two carpels, both of them fertile. In *Premna*, an imperfect 4-locular condition is derived from a bilocular condition by false septa. In *Avicennia*, the ovary is bilocular at the base, becomes imperfectly 4-locular upwards, and still higher up, the septum separates from the ovary wall on all sides, and thus is formed a 4-winged central axis. The vascular anatomy of the gynæcium of *Lippia*, *Lantana*, *Stachytarpheta* and *Petrea* shows beyond doubt that although there are two carpels present, only the posterior one is well developed and ovule-bearing. The two placental bundles represent marginal traces of this carpel. The anterior carpel is extremely reduced and represented vascularly only by its dorsal bundle. In *Lantana*, *Stachytarpheta* and *Petrea* the anterior dorsal strand bears one or two small laterals close to its base, but in *Lippia* it does not branch at all. Thus, the family shows a regular gradation in the reduction of the gynæcium. *Duranta* has four carpels, all of them fertile; *Citharexylum*, *Callicarpa*, *Tectona*, *Gmelina*, *Premna* and *Avicennia* have two carpels only, both of them well developed. In *Lippia*, *Lantana*, *Stachytarpheta* and *Petrea*, only

one carpel is well developed and bears ovules, while the other is reduced and sterile. This sterility of a carpel has nothing to do with carpel polymorphism. It stands on the same footing as the reduction in the number of stamens and the occurrence of staminodes.

While saying that "the placentation in the young ovary is parietal, the placentas subsequently uniting more or less completely in the centre of the ovary, each being rolled back right and left" Rendle (1936) mentions that in *Lantana*, *Lippia* and allied genera, the posterior carpel becomes aborted. This error appears to have resulted from a mistake in regarding the placentas as belonging to that side of the ovary from which they apparently arise. The microtome sections clearly indicate that it is the posterior carpel which is well developed (with its margins incurved into the loculus), while the anterior one is reduced. The appearance of the fertile carpel in these genera can be compared to any carpel of the syncarpous ovary of *Begonia*, where also there is a similar recurving of the carpellary margins. Warming (1932) mentions that in some genera of the family, the anterior carpel is suppressed. This statement is nearer the truth than Rendle's description.

While realizing that different floral parts of a plant need not evolve at the same speed or direction, it is seen that in the vascular supply of the calyx as well as the gynæcium, *Duranta* and *Vitex* show rather primitive features, while *Lantana*, *Lippia*, *Stachytarpheta*, and *Petrea* show comparatively advanced features in some reduction from the typical plan. The correlation between reduction in calyx and reduction in gynæcium, however, cannot be carried too far for obvious reasons.

Engler and Prantl (1909) as well as Bentham and Hooker (1883) include *Duranta* along with *Lantana*, *Lippia*, *Stachytarpheta* and *Petrea* in the same tribe. On account of great differences in the floral anatomy between *Duranta* on the one hand and *Lippia* and *Lantana*, etc., on the other, a separation of *Duranta* (along with any others that might be found to resemble it) into another tribe appears justified.

Summary

The vascular anatomy of 13 species of Verbenaceæ (each belonging to a different genus) is studied with the view of determining the interrelationships and evolutionary trends within the family. There are reductions in the calyx, androœcium and gynæcium. On grounds of floral anatomy, *Duranta* is seen to be primitive, while *Stachytarpheta* belonging to the same tribe shows reductions. A clear reduction is seen in the gynæcium, from the 4-carpellary condition of *Duranta*, to the condition seen in *Lippia*, *Lantana*, *Stachytarpheta* and *Petrea*, where, of the two carpels present, only the posterior one is well developed and ovule-bearing, while the anterior one is extremely reduced and sterile.

Acknowledgements

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Literature Cited

Bentham, G. and Hooker. J. D. 1883. Genera plantarum. London.

Engler, A. and Prantl, K. 1909. Die Naturlichen Pflanzenfamilien. Leipzig.

Junell, S. 1934. Zur Gynæcium morphologie and systematik der Verbenaceen and Labiateen. Symb. Bot. Uppsala. 4: 1–219.

Rendle, A. B. 1938. The classification of flowering plants—II. Cambridge.

Saunders, E. R. 1939. Floral morphology—II. Cambridge.

Warming, E. 1932. Handbook of Systematic Botany. London.

THE FORMATION OF LESIONS BY GASES ON MANGO FRUITS

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Introduction

A preliminary investigation on the effect of sulphur dioxide on the mango fruits (Das Gupta, Verma and Sinha, 1941) has shown that the first visible reaction is the appearance of lesions around the lenticels. The lesions are not restricted to the distal end but are distributed on the general surface of the fruits. The investigation on the formation of lesions has been carried further both with the plucked mangoes and mangoes borne on the trees, using improved methods of administering the gas with a view to get an insight into the role of sulphur dioxide on the production of these lesions.

Attempt has now been made to find out the lowest concentration of the gas which would produce lesions in enhanced periods under changed experimental conditions. A continuous current of the gas has been mostly utilised in these experiments. The investigation has been extended to include the effect of ethylene gas also both singly and in admixture with sulphur dioxide. The results are presented in this paper.

Material and Method

The experiments were carried out in two healthy* orchards which were specially selected for the purpose within the precincts of Lucknow municipality, *viz.*, Government Horticultural Gardens and Ch. Ismail's Orchard on University Road, Lucknow. The investigations were restricted to *Safeda* and *Dasehri* varieties of mango fruits at various stages of maturity while still on the trees. For laboratory experiments with plucked fruits, mangoes were obtained from the same orchards and another healthy orchard, *viz.*, Nadua.

For these experiments sulphur dioxide was usually obtained by (i) burning known quantities of sulphur and (ii) directly from cylinders where the gas was stored under pressure and supplied as such by the manufacturers.

Ethylene employed for experiments was obtained directly from cylinders where the gas was stored under pressure as supplied by Oxygen Acetylene Co., Ltd., Calcutta.

For administering a continuous current of the gases two methods were adopted:—

* The use of the word 'healthy' in relation to an orchard indicates its being free from 'necrosis' disease.

(i) The gas from the cylinders was passed through two gas washing bottles connected in series, and released through a funnel connected with the washing bottle by means of a rubber tubing. For sulphur dioxide the washing bottle contained concentrated sulphuric acid, and for ethylene, the fluid was a concentrated solution of potassium hydroxide. The fruits were held in position by suitable device at definite distances from the funnel (Fig. 1). The flow of the gas was regulated by means of an adjusting screw valve of the cylinder and by

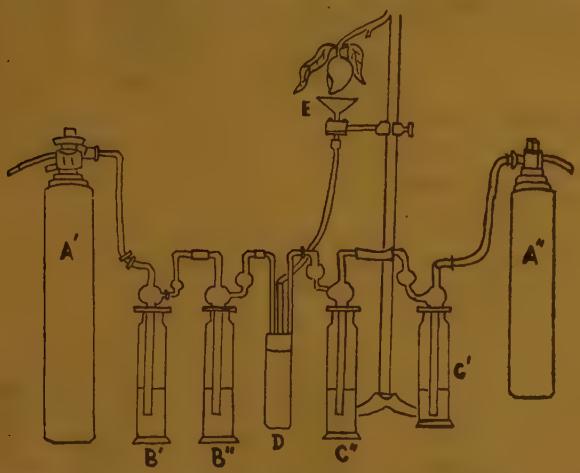

FIG. 1. Illustrating the method of administering a mixture of sulphur dioxide and ethylene gas to mango fruits

A′ .. Cylinder with sulphur dioxide gas.
A″ .. Cylinder with ethylene gas.
B′ & B″ .. Washing bottles with concentrated sulphuric acid.
C′ & C″ .. Washing bottles with concentrated potassium hydroxide solution.
D .. Mixing vessel.
E .. Funnel through which mixture of the two gases finally evolved.

suitably adjusting the Hoffman's clips interposed between the cylinder and washing bottles on the rubber tubing.

By this method the actual concentration reaching the mangoes was not controlled. It only gave the approximate maximum limit of the gas, which was variously diluted before reaching the mangoes, according to the distance between the exit of the gas and the fruits and also the velocity of the wind.

(ii) The more improved method with the help of which a continuous current of different concentrations of sulphur dioxide and ethylene could be mixed with air and administered to fruits in very small doses as developed by Datta (1944) in these laboratories for the specific purpose (Fig. 3).

A mixture of sulphur dioxide and air (or ethylene) in adequate and desired proportions is bubbled to an experimental tube containing

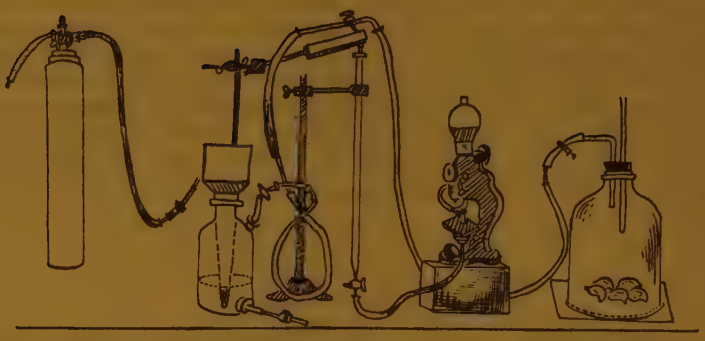

FIG. 2. Illustrating gas microburette arrangement

A′ .. Gas cylinder.
A .. Gas holder.
B .. Burette.
C .. Glass vessel containing liquid paraffin.
J .. Bell jar containing experimental fruits.

FIG. 3. Apparatus for administering small doses of sulphur dioxide to mango fruits (after Datta)

A .. Aspirator.
B & C .. Guard vessels.
A′ .. Another aspirator for air.
J .. Experimental jar containing mango fruits.
E .. Vessel from where the requisite mixture is bubbled to experimental jars.

a liquid of known density *via* a guard vessel and the rate is controlled and regulated by means of Hoffman's clips (Fig. 3). The mixture then comes to a mixing vessel where regulated amount of air is given in by an aspirating system, *i.e.*, air from an aspirator is forced out by the pressure of water and is bubbled up through a long and thin tube which was touching the bottom of a long experimental graduated tube filled with another liquid of known density. The air comes to the mixing vessel *via* another guard vessel, the rate of air being controlled by Hoffman's clips. The mixture of air and sulphur dioxide (or ethylene) in the desired proportions after being dried passes into the experimental bell jars in which the mangoes were enclosed.

To administer low doses of gases, a microburette arrangement was devised (Fig. 2).

The gas from the cylinders was transferred to gas holder A Fig. 2), the side opening of which was connected by rubber tubing to a microburette with a three-way stop-cock interposed between them, one end leading to the experimental bell jar (J) and the other to the burette (B). The lower end of the burette was connected to a glass vessel (C) supported on the tube holder of a microscope (the eye-piece and the objective holder of which were removed to hold the vessel (C). Liquid paraffin was filled in part of the burette and the vessel C (this column of paraffin worked as a manometer) so that the movement of microscope screw adjuster helped to regulate the level of the fluid and forced and known volume of the gas into the bell jar containing fruits. The gas was kept in the burette and the gas holder at atmospheric pressure.

Experimental

(1) *Effect of Sulphur Dioxide*

(*a*) *The relative size and number of lesions produced on plucked fruits*

The first set of experiments carried out in the laboratory on plucked fruits were primarily intended to determine the number of lesions formed on the skin of the fruits of *Dasehri* and *Safeda* varieties.

Freshly plucked fruits from 1½″ to 2″ in size were utilised by enclosing them in bell jars (3,500 c.c.). The fruits were released from the enclosures after necessary concentration of the gas had been administered from the desired period, and then allowed to remain in the free air. They were observed after 24 hours and the lesions formed were examined and counted.

Sulphur dioxide for these experiments was obtained by burning the requisite quantity of sulphur to produce the desired amount of sulphur dioxide gas. Weighed amount of sulphur was placed in a crucible inside the bell jar and red hot piece of glass rod (½″ in length) was introduced in the crucible which converted the total amount of sulphur into sulphur dioxide gas. The upper mouth of bell jar was then closed with a cork and sealed with paraffin to avoid leakage. The lower portion of the bell jar was allowed to rest on a glass plate to

which the basal rim of the bell jar was sealed with vaseline. The results have been tabulated and are summarised in Table I. Concentrations of 91, 182, 275 parts of sulphur dioxide mixed with 10,000 parts of air were tried for 30 minutes, 1 hour, and 1½ hours each. Five fruits were utilised for each experiment and values given in the table are an average of the number of lesions produced on all the samples.

TABLE I

Effect of Sulphur Dioxide on Dasehri *and* Safeda *fruits expressed in terms of lesions produced*

Duration of treatment	Lesions per unit area					
	Concentration (91 : 10,000)		Concentration (182 : 10,000)		Concentration (275 : 10,000	
	Dasehri	*Safeda*	*Dasehri*	*Safeda*	*Dasehri*	*Safeda*
30 minutes ..	84	41	126	92	102	137
1 hour ..	110	89	139	101	132	168
1½ hours ..	116	135	138	123	214	152

It is apparent from the table that the number of lesions produced increases with enhancement of the duration of the treatment. The number of lesions also increases with heavier concentrations. The general trend of the reaction is, however, not followed in some instances, *e.g.*, with a concentration of 275: 10,000, the number of lesions produced in 1 hour is 168 whereas, in 1½ hours, they are only 152. The explanation of this anomaly depends on the physiological condition of the different fruits and no two fruits are exactly identical at one time during the growing stage.

It will also be seen that in the *Dasehri* variety, the number of lesions produced is much greater than those produced on *Safeda* variety.

Similar experiments were repeated by giving the same concentrations for 30 minutes, 1 hour and 1½ hours duration in the laboratory with a view to measure the size of the lesions produced with each treatment. The results are embodied in Table II where the figure before the brackets denotes the number of lesions and size of the lesions in mm. is given within the brackets. Twenty lesions were counted at random on a unit area on each fruit and the average size is given in the table.

It will be seen from the above table that not only the number of lesions but also the size of these increases with the corresponding increase in the concentration. If the concentration of sulphur dioxide is fixed, the increase in the size and number of lesions is observed

TABLE II

Showing the effect of Sulphur Dioxide gas in various concentrations with 10,000 parts of air on Safeda *and* Dasehri *varieties expressed in terms of number of lesions and their size*

Time	Treatment	Variety of mangoes	Lesions per unit area of fruit in grams per size used		
			Concentration (91 : 10,000)	Concentration (182 : 10,000)	Concentration (275 : 10,000)
30 mts.	In bell jars in the lab.	*Dasehri*	84 (1·9243)	126 (2·1004)	102 (2·0086)
		Safeda	41 (1·6128)	112 (2·0492)	138 (2·1399)
1 hour	In bell jars in the lab.	*Dasehri*	109 (2·0374)	139 (2·1430)	132 (2·1206)
		Safeda	89 (1·9494)	102 (2·0086)	167 (2·2227)
1½ hours	In bell jars in the lab.	*Dasehri*	116 (2·0645)	139 (2·1399)	206 (2·3139)
		Safeda	135 (2·1303)	123 (2·0899)	158 (2·1987)

with the enhancement of the period of treatment. It will also be noticed that *Dasehri* variety under a set of experimental conditions produces many more lesions than the *Safeda* variety.

(*b*) *Varietal susceptibility*

The lowest effective dose that produces lesions in the different varieties was also determined in the orchard by using the usual gas chambers. The gas was obtained directly from the cylinders in definite concentrations in the manner described elsewhere. The gas, having been admitted in the gas chamber, was allowed to react with the mangoes of approximately 2″ in size of different varieties for fixed period. The fruits were then released and observations made after 24 hours. It has been found that *Khasulkhas* and *Benazir* varieties showed the appearance of lesions with a concentration of 46 parts mixed with 10,000 parts of air when allowed to react for 15 minutes whereas fruits of *Safeda* variety were more resistant and a similar effect with the same concentration was observed in 25 minutes. The fruits of *Dasehri* variety, however, showed the effect in 20 minutes under similar conditions of treatment. With a concentration of 46 : 10,000 the fruits showed no visible effect.

(*c*) *Continuous administering of sulphur dioxide gas to plucked fruits*

The apparatus designed by Datta (1944) and described briefly under *method* (p. 4) was set up (Fig. 3) and adjusted to give the requisite concentration of sulphur dioxide in the experimental bell jars where mango fruits intended for experimentation were introduced and bell jars closed and sealed with a mixture of vaseline and paraffin to the glass plate on which it rested.

For this experiment, *Dasehri* and *Safeda* mangoes of about the same stage of maturity about 2·5″ and 2″ in length respectively obtained

from a healthy orchard were utilised. Five fruits of each variety were used for each set of experiment.

As sulphur dioxide content of the orchard showing 'necrosis' disease was found to be approximately 47: 1,00,000, the following concentrations were tried:—

3: 1,00,000; 5: 1,00,000; 10: 1,00,000; 20: 1,00,000;
40: 1,00,000: 80: 1,00,000; 120: 1,00,000; 160: 1,00,000.

Each concentration was administered for durations of 10, 15, 20, 30, 60 and 90 minutes. After the continuous current of the desired concentration had been administered for the requisite time, the supply of gas was closed.

Similar reactions were observed in both *Dasehri* and *Safeda* varieties; even up to 90 minutes no lesions had appeared. With a concentration of 120: 1,00,000 and 160: 1,00,000, however, the fruits showed bleaching of the skin immediately after the gas had been introduced, whereas with lower concentrations no effect was noticed for 2 days. The fruits were kept under observation for 7 days and the observations are recorded in Table III.

It will be seen from the table that when mangoes were charged with low concentrations of the range 3: 1,00,000 to 20: 1,00,000, no effect was produced even when the duration was 30 minutes, whereas with increased period of treatment from 45 to 90 minutes the skin of the fruits showed a certain amount of darkening in course of time. There was, however, an evidence of the tip region showing some shrinkage of tissues when application of the gas was continued for 90 minutes. With increased concentration of the gas, *i.e.*, from 40: 1,00,000 to 160: 1,00,000, there was marked change in colour, the fruits assuming a pinkish grey tinge, and the shrinkage of the tissues at the tip region was still more pronounced in comparatively shorter periods.

A striking difference in the effect produced as compared to the results observed under orchard condition (Das Gupta *et al.*, 1941) is the complete absence of lesions. Here the general skin turned greyish and subsequently the tip showed certain amount of shrinkage. With heavy doses, bleaching of the fruits occurred.

(*d*) *Continuous administering of sulphur dioxide gas to fruits on trees*

(i) *Low, unknown concentration of the gas.*—Experiments were carried out to ascertain the effect of continuous current of low concentration of the gas on mango fruits from the blossom right up to a certain stage of maturity when still attached to the trees.

A device was fitted up at the Horticultural Garden, Lucknow, where the gas from a cylinder containing sulphur dioxide under pressure was passed through gas washing bottles containing concentrated sulphuric acid, the number of bubbles of definite size passing through the washing bottle gave the indication of the quantity of gas reaching the objects at a definite time. Each bubble gave ·157 c.c. of the gas so that the concentration of the gas diluted with air reaching the fruits

TABLE III

Showing the effect of continuous current of Sulphur Dioxide gas of different concentrations on mangoes of Safeda *and* Dasehri *variety*

Concentration: SO_2 per 1,00,000 parts of air	Effect of sulphur dioxide gas on mangoes						
	10 mts.	15 mts.	20 mts.	30 mts.	45 mts.	60 mts.	90 mts.
3	..	..	..	..	Colour changed to greyish green on 3rd day	Dirty greyish pink colour on 4th day	Colour of skin dirty greyish green after 48 hrs. tip shrinking
5	..	..	..	..	do	do	do
10	..	..	..	..	do	do	do
20	..	..	..	..	do	do	do
40	..	..	Tip shrinking observed on 3rd day accompanied by colour change	Tip shrinking on 3rd day accompanied by colour change	Colour changed to greyish green after 48 hours. Tip shrinking observed on 3rd day	Colour changed to greyish green after 48 hours. Tip shrinking observed on 3rd day	Colour changed to greyish green after 48 hrs. Tip shrinking observed on 3rd day
80	..	..	Tip shrinking observed on 3rd day accompanied by colour change	Tip shrinking on 3rd day accompanied by colour change	Colour changed to greyish green after 48 hours. Tip shrinking observed on 3rd day	Colour changed to greyish green after 48 hours. Tip shrinking observed on 3rd day	Colour changed to greyish green after 48 hrs. Tip shrinking observed on 3rd day
120	Bleached immediately; pinkish grey colour after 12 hours. Shrinking of general surface on 7th day	Bleached immediately; pinkish grey colour after 12 hours. Shrinking of general surface on 7th day	Bleached immediately; turning yellowish green which assumed pinkish tinge subsequently after 12 hours. Shrinking of general surface on 7th day	Bleached immediately; turning yellowish green which assumed pinkish tinge subsequently after 12 hours. Shrinking of general surface on 7th day	Bleached immediately; turning yellowish green which assumed pinkish tinge subsequently after 12 hours. Shrinking of general surface on 7th day	Bleached immediately; getting greyish colour. Shrinking of general surface on 7th day	Bleached immediately; getting greyish colour. Shrinking of general surface on 7th day
160	do	do	do	do	do	do	do

when held at 6″ distance from the funnel was in the ratio 16 of sulphur dioxide: 1,52,000 of air, each second, assuming that wind was calm.

The apparatus was run for 5 hours every day, in two instalments of 2½ hours morning and evening. Only *Safeda* variety was utilised.

This experiment gave only an approximate idea since the concentration of the gas as it passed out in the open atmosphere got diluted and could not be controlled under the prevailing condition of the experiment when the velocity and direction of the wind used to be uncertain. It was apparent that the concentration reaching the mangoes was much lower than in the funnel itself. The results are given in Table IV.

TABLE IV

Showing the effect of administering a continuous current of Sulphur Dioxide gas on the mango fruits at various stages of maturity while on the trees

Stage of development of the fruit	Effect of the gas produced on the fruits
Inflorescence stage ..	Petals and sepals turned brown which become still darker in course of time. The entire inflorescence become very brittle to touch. The inflorescence ultimately dried away in 2 days
Fruit developed to almost the size of pea	Lesions appeared after 48 hours which coalesced within 24 hours. The entire fruits ceased growth, turned brown and fell off to the ground by itself on the 5th day
Fruits ½″ in length ..	Developed brick-red lesions. Growth ceased and in 5 days the fruits dried turning dark brown ; ultimately fell off
Fruits 1″ in length ..	Brick-red coloured lesions appeared. With further administration of the gas the spots coalesced to form patches. General growth of the fruit is hindered
Fruits 2″ in length ..	do

It will be seen from the above table that the effect of sulphur dioxide on blossom and on very young fruits, developed to the size of pea, was fatal. The petals and sepals of the flowers were adversely affected, the setting of the fruits was hindered and the entire blossom dried out. In the very young fruits, brick-red spots appeared in a short period and the injury was such that the delicate fruits ceased growth and ultimately dried within 5 days.

In older and larger fruits similar lesions were produced, but it took them much longer time to coalesce and the mangoes did not fall off, but continued to grow with the patches of lesions, although the rate of growth seemed to be very much hindered. Eventually they shrivelled, became completely useless and fell off to the ground.

(ii) *Known concentration of the gas.*—The effect of continuous current of known concentration of sulphur dioxide under controlled condition was studied in a healthy orchard (Ch. Ismail Orchard) which was situated within easy approach of the University laboratories.

Fruits of *Safeda* variety which had developed to about ½" in length were utilised.

The apparatus designed by Datta (1944) was utilised with necessary modifications to suit orchard conditions. The end tube through which the desired concentration of the gas passed (Fig. 4) into the jars was connected to a five-way tube each of which was connected to a corresponding bell jar.

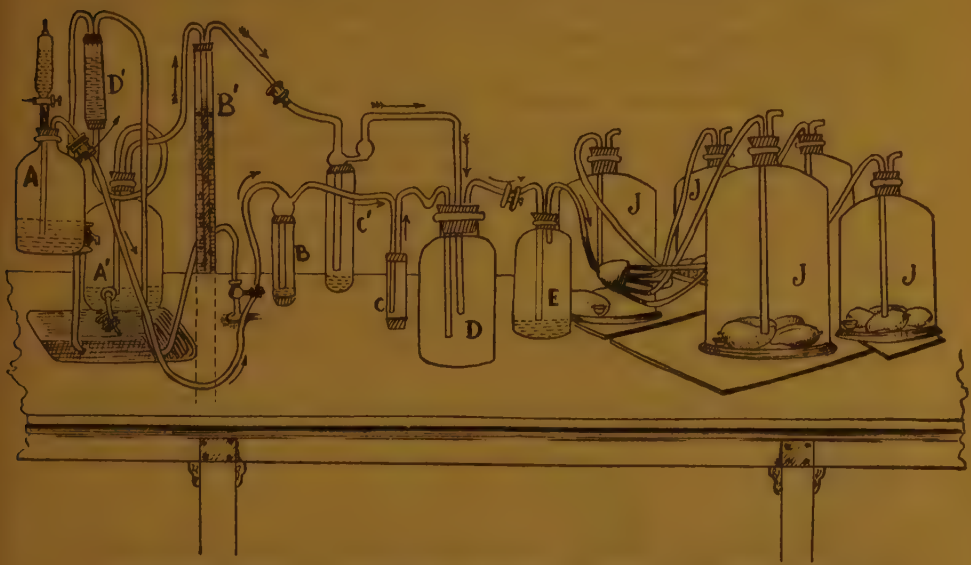

FIG. 4. Apparatus as explained in Fig. 1 to suit orchard condition. A. large glass container filled with water placed on high stool is replaced of water tap. The experimental jar holds mangoes while still attached to the tree. The lettering on the apparatus signify the same meaning as indicated in Fig. 3.

The bell jars, each with 5-7 mangoes hanging inside, were tied to the branches of the trees. The open mouth of the bell jar was lightly closed with thin muslin to allow the exchange of gases from the outside atmosphere and yet not be disturbed by the velocity of the wind. A thermometer was hung in each bell jar to record any variation in the temperature with respect to the temperature outside the bell jar. Two bell jars were also kept as controls.

The sulphur dioxide content in the bell jars was periodically tested to check the concentrations by absorbing it on the iodine solution (containing a crystal of potassium iodide) and then titrating it against thiosulphate (Lunge and Ambler, 1934).

I. *Effect of continuous current* (5 : 10,000)

A continuous current of sulphur dioxide having a concentration of 5 : 10,000 was administered continuously for 9 hours every day, after which each day the experiment was stopped and fruits were

released from the chambers until next day's experiment. The experiment with the concentration mentioned above was continued for 22 days. The temperature inside the bell jar proved to be higher than outside by 1 to 1·5° C.

The experimental fruits were kept under observation. No lesions or any colour change was visible on the fruits, the mangoes were similar to ones in control jars.

It was, therefore, obvious that an exposure of 5: 10,000 concentration of SO_2 gas for 22 days at 9 hours per day was unable to produce any lesions in the fruits.

II. *Effect of continuous current* (7: 10,000)

A concentration of 5: 10,000 having failed to produce any visible effect even in 22 days the concentration of the gas was increased to 7: 10,000 and experiment run on similar lines.

On the 5th day of the change the usual brick-red coloured lesions appeared on the skin of the fruits. The experiment was continued with the result that the size and number of lesions increased with tendency to coalesce. In the next 10 days after the appearance of lesions, the fruits had started falling off with increased injury due to the coalescence of the lesions.

It is therefore evident that for the production of lesions a certain minimum concentration of the gas is essential below which the lesions do not appear even if the period of treatment be considerably prolonged.

(2) *Effect of Ethylene*

The effect of ethylene was studied on mango fruits while on the trees in the orchard as well as plucked fruits in the laboratory.

(i) *On fruits borne on the trees, in gas chambers.*—For studying the effect of the gas under static condition in the orchard, the usual gas chambers as already referred to with regard to sulphur dioxide treatment (Das Gupta *et al.*, 1941) were used. After the requisite period of treatment with the gas the fruits were released from the chambers and allowed to develop in the open atmosphere.

The first set of experiments was done with the gas obtained directly from cylinders as supplied by the manufacturers, Messrs. The Acetylene Co., Ltd., Calcutta. The flow of the gas was controlled by the screw valve attached to the cylinder. For finer adjustments, pinch cocks mounted on the delivery tubing were employed. The quantity of the gas administered was indicated by the number of bubbles per minute in the gas washing bottles filled to a known height which were interposed between the cylinder and the final outlet of the gas into the chambers. The bore of the tubing inside the wash bottle was known and it was thus possible to determine the exact quantity of gas delivered in a certain time.

Dasehri and *Safeda* fruits of about $2\frac{1}{2}$" and 2" in length at Horticultural Gardens, Lucknow, were utilised for experiments. Five

replicates of each set were done. The mangoes were examined 24 hours after the treatment. The results are summarised in Table V. The sign (+) in the table indicates the appearance of small brown lesions around the lenticels on the fruits and (—) the absence of any visible effect.

TABLE V

Showing the effect of Ethylene Gas of different concentrations on Dasehri *mangoes as seen after 24 hours*

Concentration of ethylene per 10,000 parts of air	Duration of the treatment in minutes	Effect of the gas on mangoes
108	15	+ + +
54	15	+ +
32	15	+
22	15	+

It will be seen from the above table that in all the concentrations of ethylene used, lesions develop on 15 minutes exposure. With the lowest dose (22: 10,000) the number and size of the lesions attained within 24 hours after the treatment remained constant. With heavier doses the number of lesions continued to increase and showed tendency to coalesce.

A similar experiment was carried out with a concentration of 22: 10,000 parts of air, the lowest dose used in the previous experiment but the time of exposure was varied, *viz.*, 30, 15, 7 and 5 minutes. The results are shown in the following table:—

TABLE VI

Showing the effect of Ethylene Gas on Dasehri *mangoes of a fixed concentration in varying periods as observed 24 hours after the treatment*

Concentration of ethylene per 10,000 parts of air	Duration of the treatment in minutes	Effect of the gas
22	30	+ +
22	15	+
22	7	—
22	5	—

The table indicates that with a short exposure of 7 and 5 minutes no apparently visible effect is produced whereas in 15 minutes, the

brown coloured lesions are evidenced which are more numerous and larger in size when the treatment is given for 30 minutes.

(ii) *On plucked fruits treated with gas by microburette arrangement (laboratory experiments).*—The effect of ethylene gas in comparatively low concentrations was studied on plucked fruits in the laboratory.

Freshly plucked *Dasehri* mangoes from healthy orchard, about 2" long, were kept in bell jars. Ethylene was administered by means of microburette arrangement described elsewhere. After administering ethylene gas in the desired quantity, the bell jars were completely closed and sealed to prevent any leakage of the gas. Five replicates were kept. Controls were kept in closed bell jars as well as in open ones. The fruits in the bell jars were kept under observation for 10 days. The results obtained for different concentrations are recorded in Table VII. The observations recorded in the different replicates were similar.

TABLE VII

Effect of Ethylene Gas on plucked Dasehri *fruits*

Name of gas	Concentration of ethylene per 10,000 parts of air	Effect of the gas on fruits
Ethylene	1	Fruits remained green till the 5th day. Ripening started on 6th day. No lesions appeared. The skin colour changed to yellowish green
	10	The ripening started earlier. The colour of the skin became blackish green on 10th day. Large number of lesions appeared on the skin
	20	Quick ripening. Lesions appeared. Coat remained firm. The skin did not turn black but remained yellowish green
	30	Very quick ripening. Innumerable lesions appeared. Colour changed from green to yellow
	40	Bleached appearance of the fruit. The colour changed after an hour. Presence of lesions
	50	do
	Controls (open jars)	Healthy green colour. Fruits appear fresh even on 7th day
	(Closed jars)	Fruits normal; the skin colour changed to darkish yellow. Coat firm

It will be seen from Table VII that dose of 40 : 10,000 and 50 : 10,000 ethylene bleached the fruits altogether. Lower concentrations, however, of 10 : 10,000, 20 : 10,000 and 30 : 10,000 induced ripening and the usual lesions also appeared. A dose of 1 : 10,000 only induced ripening and no lesions appeared.

(iii) *On plucked fruits treated with continuous current of the gas (laboratory experiment).*—The other method of treatment of fruits with ethylene was by administering a continuos current of the gas of known concentration for a certain fixed period to the freshly plucked fruits.

For this purpose, the specially devised apparatus referred to in the experiments with sulphur dioxide was utilised. Necessary alterations in the apparatus were introduced to suit this gas. Concentrated sulphuric acid was replaced by concentrated solution of potassium hydroxide.

Dasehri and *Safeda* fruits about $2\frac{1}{2}''$ and $2''$ in length respectively were enclosed in a bell jar. Five fruits of each variety were used for each set of experiment. There were 5 replicates.

The mixture of air and ethylene in the desired proportions was admitted into the bell jars containing fruits. The concentration of ethylene in the experimental jars was tested at frequent intervals to check the accuracy of the concentration of the gas. The following concentrations of ethylene 3, 4, 10, 20, 40, 80, 120, 160 per 1,00,000 parts of air were tried for durations of 10, 15, 20, 30, 45, 60 and 90 minutes each.

After a continuous current had been given for the desired time, the inlet and outlet of the bell jars were closed up with pinch cocks. The fruits in each bell jar were kept under observation for one week.

The results are recorded in Table VIII.

It will be seen from the above table that doses of 3 : 1,00,000 and 4 : 1,00,000 of ethylene gas even when administered for 90 minutes do not produce any visible effect on the mango fruits. Higher doses, however, (concentrations 10 to 80 : 1,00,000) induced ripening and the colour of the skin turned yellow. 10 : 1,00,000 of ethylene when given for 60 and 90 minutes, apart from initiating ripening also showed the appearance of lesions while 40 : 1,00,000 and 80 : 1,00,000 ethylene caused the lesions in lesser period (10 minutes).

Ethylene, 120 and 160 in 1,00,000 parts of air, however, in the shortest duration of 10 minutes charge, brought about the formation of lesions accompanied with ripening and yellowing of the skin. With increased period of charge of these doses the skin of the fruit showed the change of colour to blackish grey. It should be noted that the experimental fruits were kept in the bell jar for one week after the necessary charge and then the observations were made.

(3) *Effect of Sulphur Dioxide and Ethylene in Admixture*

It was evident from the experiments with sulphur dioxide and ethylene administered separately to the healthy mangoes that the effect on the fruits in either case was in the formation of lesions of brick-red or brown colour. The characteristic black-tip (necrosis) was never produced.

Experiments were therefore carried out using mixture of sulphur dioxide and ethylene in different proportions.

TABLE VIII

Showing the effect of continuous current of Ethylene Gas of different concentrations on mangoes

Concentration of ethylene per 1,00 000 parts of air	Effect of ethylene on mangoes						
	10 mts.	15 mts.	20 mts.	30 mts.	45 mts.	60 mts.	90 mts.
3	..	..	..	..	..	..	..
4	..	.	..	..	..	..	..
10	..	Yellowing, Ripening initiated	Small lesions visible, quick ripening	Small lesions visible, quick ripening	Small lesions visible, quick ripening	Numerous lesions appeared, colour of the skin yellowing	Numerous prominent lesions found. Colour yellow
20	..	Skin yellowing. Ripening (premature)	Coat firm and skin yellowing	do	do	Ripening, with above effects	Colour yellow, with above effects
40	Skin of the fruit yellowing	do	do	do	do	do	do
80	do	do	do	do	do	do	do
120	Ripening, skin yellowing, minute lesion visible	Ripening, skin yellowing, minute lesion visible	Lesions appeared. Skin blackish green on 7th day. Ripening, fruit pulpy	Lesions appeared. Skin blackish green on 7th day. Ripening, fruit pulpy	Larger number of visible lesions showing coalescence. Skin turned greyish. Ripening, skin coat loose	Larger number of visible lesions showing coalescence. Skin turned greyish. Ripening skin coat loose	Larger number of visible lesions showing coalescence. Skin turned greyish. Ripening, skin coat loose
160	do	do	do	do	do	do	do

(i) *On fruits borne on the trees, in gas chambers (orchard condition).*—For this experiment sulphur dioxide and ethylene were taken from the cylinders as supplied by the manufacturers. The gases from the two cylinders bubbled simultaneously through gas washing bottles at the desired rate and then passed through a T-tube into a common bottle where they freely mixed with each other before being administered into the gas chambers. The flow of the gases was controlled and regulated in the manner described elsewhere. The actual quantity of the gas was determined by counting the number of bubbles through the bore of the glass tubing inside the washing bottles.

The details of the concentration and duration of the reaction and result of each treatment are given in Table IX where (+) denotes the appearance of dark brown lesions and (−) denotes their absence. The increased number of (+) signs shows the increased number of lesions produced.

TABLE IX

Showing the effect of mixture of Sulphur Dioxide and Ethylene on mangoes (Dasehri *variety*) *for different concentrations and varied periods*

Concentrations of gases		Duration of the reaction in minutes	Effect visible on the fruits
SO_2 parts per 10,000 of air	Ethylene parts per 10,000 of air		
19	22	30	−
29	32	30	+ +
48	54	30	+ + +
96	8	30	+ + + +
29	32	15	+
48	54	15	+ +
96	108	15	+ +

It will be seen from the above table that the lowest dose that produces effect is 29 : 10,000 of sulphur dioxide in admixture with 32 : 10,000 of ethylene if administered for 15 minutes. A mixture of 19 and 22 of sulphur dioxide and ethylene respectively per 10,000 parts of air is ineffective when given for 30 minutes. Other higher concentrations bring about large number of dark brown lesions, which increase in number and size with corresponding increase in the concentration. On the contrary, when these gases are administered singly a much larger dose of sulphur dioxide is required to produce the lesions in the specified time. It has been found elsewhere that singly 32 : 10,000 of ethylene is required to produce lesions in 15 minutes in *Dasehri* fruits and 46 : 10,000 of sulphur dioxide produces lesions in 30 minutes on fruits of *Safeda* variety. An explanation to this anomaly

is found when we consider the manner in which these two gases can react. In the presence of moisture, a certain amount of SO_2 (sulphur dioxide) will form H_2SO_3 (sulphurous acid) which in very small quantities can be transformed into sulphuric acid. Sulphuric acid so formed will absorb ethylene to form ethylene hydrogen sulphate, so that the reactional value will be slightly reduced in the present experimental conditions. However, it is clear that the two gases in mixture react individually to produce lesions.

(ii) *Gas administered to plucked fruits by microburette arrangement (laboratory experiments).*—The effect of the two gases in mixture in very low concentrations was next studied in the laboratory. For these treatments the gases in the required concentration were administered with the help of microburette referred to before (Fig. 2). The gases were administered simultaneously through two glass tubes fitted on the cork over the mouth of the bell jars. The inlet of the gases were completely closed up after the desired dose of the gases had been passed into the bell jars. *Dasehri* fruits, freshly plucked from a healthy orchard, measuring $2\frac{1}{2}''$ in size, were utilised for the treatments. Five fruits were taken for each treatment. Usual controls were kept where mangoes were kept in ordinary atmosphere under bell jars and were examined after one week.

Two replicates for each treatment were tried and the results of the two were similar and are summarised in Table X.

It will be seen from the above table that with heavy doses of (50 : 10,000) concentration of sulphur dioxide and ethylene, the fruits are intensely bleached, and there is profuse formation of dark brown coloured lesions and the tissues at the tip show shrinkage. With (30 : 10,000) concentration of the gases, apart from bleaching of the skin, shrinkage of the tissues at the tip and formation of lesions, the fruits had shown pulpiness—a condition depicting initiation of ripening. With doses of (10 : 10,000) and (20 : 10,000) in mixture of equal concentration of each gas, comparatively fewer and smaller lesions are produced, the skin colour shows yellowing and darkish colouration. With 10 : 10,000 of ethylene and 1 : 10,000 of sulphur dioxide ripening is induced and very few lesions are formed, on the other hand with 1 : 10,000 of ethylene and 10 : 10,000 of sulphur dioxide no lesions appeared.

(iii) *Continuous administering of the gases to fruits on trees (variable concentration).*—As in other experiments with sulphur dioxide separately, a continuous current of the mixture of ethylene and sulphur dioxide was administered to mangoes of all stages beginning from the blossom up to and advanced stage of maturity.

As referred to before a simple arrangement was fitted up at the Horticultural Gardens, Lucknow. The gases from the cylinders containing sulphur dioxide and ethylene stored under high pressure bubbled through gas washing bottles containing concentrated sulphuric acid and concentrated potassium hydroxide solution respectively, which were interposed between the cylinders on the one side and on the other

TABLE X

Showing the effect of mixture of Ethylene and Sulphur Dioxide in varying proportions on the mango fruits (Dasehri *variety*)

Concentration of gases per 10,000 parts of air		Effect of combined gases produced on the fruit in one week
Ethylene	SO_2	
1	10	Fruit remained green for 2 days. Changed colour on the 3rd day due to ripening. No lesions formed
10	1	Early ripening. Lesions present. Colour changed from green to blackish green
10	10	Skin pale and bleached. Colour yellowish green with darkish tinge all over the fruits. Small lesions formed
20	20	do
20	30	Bleached altogether. Lesions formed, shrinkage of the tip region of the fruit
30	20	Colour changed to yellow due to ripening. Lesions formed. Shrinkage of tips of the fruits
30	30	Quick ripening. Skin bleached. Lesions formed. Shrinkage of the tissues at the tip
50	50	Large number of lesions formed. Shrinkage of tissues at the tip. Fruits heavily bleached

side a common mixing bottle through a T-tube. The gases were allowed to mix in a bottle in definite proportion. A funnel was connected through rubber tubing to the mixing bottle and held at definite distance (6″, 9″, 12″ and 15″) from the experimental fruits by a suitable device (Fig. 1). The experiment was carried out for 4 hours every day—2 hours in the morning and another 2 in the evening. The amount of ethylene and sulphur dioxide evolving per minute from the funnel was 10 c.c. and 9·42 c.c. respectively at atmospheric pressure and 30° C. and the concentration of the gas reaching the fruits as mentioned elsewhere was variable according to the environmental conditions.

It was seen from the experiment that the results which refer to various distances (6″, 9″, 12″ and 15″) from which the gases were supplied to fruits were more or less similar except that the fruits held nearer were correspondingly affected earlier. The nature of the effect produced on the fruits from blossom upto the nature stage are described in Table XI for experiments in which treatment was given from a distance of 6″.

It will be seen from the Table XI that the effect of gas is fatal to the inflorescence and very young fruits. The sepals and petals are rendered dark brown and the setting of the fruits completely stopped.

TABLE XI

Showing the effect of continuous current of Sulphur Dioxide and Ethylene in admixture administered to Dasehri *fruits at different stages of maturity*

Stage of development of fruits	Effect of the gas produced on the fruits
Inflorescence stage	The effect is visible after 3 days. The colour of the petals and sepals becomes dark brown. Setting is hindered. The inflorescence ultimately dries
Fruits from the size of mustard to pea	Brownish black spots appear after 4 days. Very young fruits become totally dark and dried. All the fruits ultimately turned brown by coalescence and dried away
Fruits ½"	Developed dark brown spots. Growth ceased. In 4 days time some fruits which were nearest the outlet of the gas were showing symptoms of drying due to coalescence of spots
Fruits 1" in length	After full 4 days treatment dark brown lesions appeared around the lenticels all over the skin of the fruit. With more of the treatment the lesions coalesce to form larger patches. The growth of the fruits is retarded and usually finally fall off
Fruits 2"	do

Very young immature fruits develop spots which quickly coalesce to give a dark colour to the entire fruit, the injury being so acute that the fruits dry out without development. On the more mature fruits when they have attained the size of 1" to 2" the effect is expressed by the production of dark brown lesions around the lenticels on the skin of the fruits. The number and size of lesions increase with increased duration of treatment. The blossoms and very young fruits take the effect in 3 days, while the more mature fruits are affected after a treatment of 4 days.

DISCUSSION

Sulphur dioxide.—It has been demonstrated that sulphur dioxide is one of the most important of the toxic constituents in the smoke of these brick kilns which is hardly different from those emitted by the chimney of other industrial concerns where coal is burnt.

There is extensive literature on the effect of sulphur dioxide on vegetation. One of the earliest detailed studies on the effect of sulphur dioxide on vegetation was made by Schroeder and Reuss in 1883. They have described with illustrations the type of acute markings on many conifers and deciduous trees. In the case of conifers, the tips of needles show the characteristic damage. Discolourations on the bark of young plants and the effects on the branches are also mentioned. In young cereals and grasses the tips of leaves first become red, then yellow and eventually white.

Another very early study of the sulphur dioxide problem was made in 1903 by Haselhoff and Lindau. Most of the symptoms of the sulphur dioxide effect stated there were very similar to those described by Schroeder and Reuss. They have found that of the cultivated fruit trees plum is the most susceptible and cherry somewhat resistant.

A number of papers have been published on the effect of sulphur dioxide on vegetation during the last decade. Zimmerman and Crocker (1930) showed that the leaves of dicotyledonous plants become spotted and marked between the veins, the tissues round about the veins remaining comparatively resistant. According to them the age factor in the leaves in the effects of sulphur dioxide was important. Middle-aged leaves were most sensitive, the older ones were intermediate, while the youngest ones were the most resistant.

The rapid industrialisation of European countries brought the problem of smoke injury to greater prominence. The National Research Council of Canada was prompted to undertake a continued investigation lasting for 8 years on the effect of sulphur dioxide on vegetation and published the results of enquiry in a book form (1939) where Morris Kats, Ledingham and McCallum have given the result of their extensive investigations, reviewed the existing literature and described with illustrations the symptoms of injury due to sulphur dioxide on a number of herbs, shrubs, garden plants, annuals and cereals. They have also discussed the relative susceptibility of different plants to sulphur dioxide. They have essentially confined their attention to leaves or leafy structures.

Biraghi (1939) described the injuries observed on the branches of walnut trees growing in the vicinity of chemical works. These injuries have been attributed to sulphur dioxide fumes and nitrous gases. The lesions resembled cankers, the bared tissue being black or in worse cases, violaceous red and cracked. Setterstrom and Zimmerman (1939) published their results of study on the influence of various environmental factors such as humidity, temperature, quality of soil, etc., on the susceptibility of plants to sulphur dioxide injury.

Metcalfe (1941) gave an account of the injury to green-house plants by low concentrations of sulphur dioxide. The injury was observed in the nature of shedding of flowers, buds and leaves of Begonias and other plants and the premature death of buds and flowers of orchids.

Most of the work mentioned above relates to the effect of sulphur dioxide on the vegetative parts of the plants. Hardly any work has been done on the effect of this gas on fruits. Ramsay (1932) described sulphur dioxide injury to tomatoes which is essentially a storage ailment due to sulphur dioxide treatments to prevent decay by organisms.

Dopp (1931), however, has demonstrated the adverse effect of sulphur dioxide on floral structures and fruiting. The effect may be indirect, by injuries to the foliage, or direct, involving effects on the formation and maturing of anthers or pathological disturbances in stigma, style, ovary or even in young embryos following fertilisation.

The effect of sulphur dioxide on the mango fruits has been described by Das Gupta *et al.* (1941) who have shown that sulphur dioxide, when administered in concentration above a certain minimum, produces brick-red coloured lesions around the lenticels on the skin of the mango fruit.

The present investigation using improved technique with plucked healthy *Dasehri* and *Safeda* mangoes in the laboratory and with mangoes while still attached to trees substantially confirm the previous results. It has again been shown that the injury produced is first expressed as small reddish minute spots which deepened into brick-red coloured lesions around the lenticels.

The minimum dose required to produce the lesions by administering the gas as obtained from the manufacturers proved to be somewhat lower in the present investigation. The results with gas administered by the same method showed certain amount of difference, *e.g.*, effect was observed with a minimum quantity of 46 : 10,000 in 20 minutes on *Safeda* variety whereas the previous results indicated no visible effect with this concentration even in 1 hour.

The reason for these differences seems to be intimately related to physiological conditions of the fruits at the time of treatment. The mangoes in two different years although of the same variety in the same orchard are not physiologically identical, neither are the immediate environment in the field exactly similar. These influence the diffusion and penetration of the gas in the mango fruits and, therefore, are apparent for the differences observed. Katz and Lathe (1939) have also pointed out the variations in the susceptibility to sulphur dioxide depending on the environmental factors and physiological conditions of the plant organs.

Varietal difference in the production of lesions is clearly demonstrated by the results obtained with *Dasehri* and *Safeda* varieties. The former variety showed pronounced lesions with a concentration of 46 : 10,000 of sulphur dioxide in 20 minutes whereas the latter under similar treatment produced lesions in 30 minutes. *Benazir* and *Khasulkhas*, more or less, are nearer to *Dasehri* in their susceptibility to sulphur dioxide effect and differ considerably with *Safeda* variety.

The effect of the gas on the fruits before fertilisation (blossom stage) right upto the maturity showed that smaller the fruits, the more quickly were they affected. Thus the blossom was affected and dried up within 4 days on application of the gas directly every day for 5 hours in the open atmosphere, the delivery of the gas being ·157 c.c. per second. The petals, sepals and the stigma initially became brown coloured and ultimately shrivelled and dried. Fruits which had attained the size of pea or half an inch in length also were similarly affected by developing lesions which soon coalesced but these took correspondingly longer duration. The more mature fruits (1″ to 2″ long) developed the usual lesions and were the last to be affected.

The size of lesions both in *Dasehri* and *Safeda* were directly proportional to the concentration of the gas administered up to a certain

maximum beyond which the gas effect was visible on the entire surface of the fruits by the coalescence of lesions. The number of lesions per unit area shows an increase with the concentration of the gas at low concentrations. It is to be noted here that the lesions are produced round lenticels which are usually fixed in number. With lower concentrations some of these may not be affected, the effect becoming visible either with the increase in concentration or if the gas is allowed to react for a longer period.

By giving to plucked fruits a continuous current of low concentrations ranging from 3: 1,00,000 to 160: 1,00,000 parts of air for different periods (from 10 minutes to 90 minutes) and then keeping the fruits enclosed in bell jars with the gas, interesting observations have been made. With these low doses on plucked fruits enclosed in a bell jar for one week under the conditions stated above, no lesions were formed; nevertheless, the colour of the skin was considerably bleached with heavier concentrations, whereas, with lower concentrations the colour of the skin became greyish and a certain amount of shrinkage of the tissues at the tip region was observed usually with lower concentrations, while with heavier concentrations (120: 1,00,000 and 160: 1,00,000) the entire surface of the fruits showed shrinking.

An important advance in these studies was evidenced when a continuous current of sulphur dioxide was given by means of a specially devised apparatus which did not produce any visible effect with a concentration of 5: 10,000 administered continuously 9 hours every day for 22 days. An increase of the concentration to 7: 10,000 about 1½ times the original concentration produced lesions on the 5th day after this change had been made. This confirms the result obtained by Das Gupta *et al.* (1941), that for the formation of lesions a certain critical concentration of the gas is required depending on the age and physiological condition of the fruit, below which the fruits do not react to form lesions even though the period be considerably prolonged. But while the concentration obtained by them was 8: 10,000 in the present case it has shown to be 5: 10,000.

Kats *et al.* (1939) have described in detail the symptoms of sulphur dioxide injury on different kinds of leaves. On yellow pine and Douglas fir, the symptoms of injury were exhibited as a reddish discolouration of the leaves with subsequent shrinkage of tissues and defoliation. In the leaves the sulphur dioxide enters through the stomata which are far more numerous and thus the spots appear uniform otherwise the external symptoms appear to be similar with those observed on mangoes where the gas enters through the lenticels and initially effects the area around it.

As regards the formation of necrosis the present investigation clearly indicates the sulphur dioxide only produces lesions on the general surface of the fruit. Under no condition of experimentation employed here have any of the effects of the gas been found to be localised at the tip region to suggest any similarity with symptoms of necrosis disease. It is apparent from these experiments that the sul-

phur dioxide gas under these experimental conditions is unable to cause the disease when acting individually.

Ethylene.—Amongst other toxic constituents of the coal fumes after sulphur dioxide, ethylene is the next most injurious to plants. Girardin as early as 1854 recorded observations on the effect of illuminating gas (which contains a high percentage of ethylene) on vegetation. Crocker and Knight (1908) made interesting studies on the effect of ethylene on carnations (floral structures). They found that a 3 days exposure to 1 : 20,00,000 ethylene causes the closing of the flowers already open. Harvey and Rose (1915) described the injurious effect of ethylene and illuminating gas on the roots of numerous plants. The effect of ethylene on fruits has been extensively investigated by numerous workers. Regeimbal, Vacha and Harvey (1927) showed that the respiration of bananas doubled or even trebled in ethylene (1 part of ethylene mixed with 1,000 parts of air). Denny (1936) has discussed the increased respiration of lemons with very low concentrations of ethylene, 1 : 1,000 to as low as 1 : 1,00,000. Allen (1930) found that ethylene-treated apples became softer and yellower than non-treated ones.

Most recent work on ethylene relates to its value as a protection against diseases. Bates (1936) found that ethylene-treated fruits developed only a negligible amount of scald under storage conditions. Winston (1937) refers to the use of ethylene colouring process of citrus fruits and their resistance to fungal attacks.

The effect of ethylene gas on mangoes has been studied by Ranjan and Jha (1940) and Sen (1943). A preliminary report of our observations on these investigations was communicated to the Imperial (now Indian) Council of Agricultural Research, India, in 1942. The treatment of the fruits at different stages of maturity in the orchard with ethylene had shown that brown lesions were produced around lenticels on the skin of the fruits. In the gas chambers these lesions are produced with a concentration of 22 : 10,000 in 15 minutes. The spots or lesions increased in size with heavier concentrations forming dark brown patches on the skin of the fruit.

Plucked fruits in sealed bell jars treated with very low doses in the laboratory (1 : 10,000) induced ripening and colour of the skin changed to yellow on the 5th day without the formation of lesions. A heavier concentration of ethylene (10 : 1,00,000), however, under similar conditions produced lesions as well as induced ripening. A continuous current of the gas (10 : 1,00,000) administered to fruits for 20 minutes and the fruits retained in gas-filled containers for 7 days produced lesions and ripening, while lower concentrations of the gas, 3 : 1,00,000 and 5 : 1,00,000 when given continuously for 60 and 90 minutes showed no apparent effect even on the 7th day and the fruits remained green and healthy.

A strong concentration (120 : 1,00,000) under similar conditions of treatment rendered the skin coat loose accompanied by formation of large brown patches on the skin.

These observations are at variance with those observed by Ranjan and Jha (1940) who found that 'Black-tip' appears when large doses of ethylene are administered continuously for a number of days while Sen's results (1943) are similar to those described here.

The only work on the combined effect of sulphur dioxide and ethylene on mango fruits is that of Ranjan and Jha (1940) who appear to have found that 1 : 1,000 of ethylene and 1 : 10,000 of sulphur dioxide mixture produces 'Black-tip' disease. The experiments carried out in this laboratory, however, failed to confirm their results. It shows, on the other hand, that the effect of ethylene and sulphur dioxide in admixture is similar to that produced by the gases individually. The usual dark brown coloured lesions were produced all over the skin of the fruit. 29 : 10,000 of sulphur dioxide and 32 : 10,000 of ethylene produced lesions when administered in gas chambers on fruits attached to the trees, while very heavy doses of sulphur dioxide and ethylene affect the fruits so severely that they are completely bleached due to the destruction of chlorophyll. The entire fruit is subsequently turned dark-brown and in course of time drops off.

Very low concentrations (the mixture of ethylene, 1 : 10,000 and sulphur dioxide, 10 : 10,000) induced ripening only, while at a slightly higher concentration of both the gases (10 : 10,000) lesions are formed together with ripening. Individually ethylene induces ripening accompanied by formation of lesions at 12 : 10,000 while sulphur dioxide under slightly altered conditions of treatment in the laboratory at 12 : 10,000 causes shrinkage of the tissues and bleaching of the skin without the formation of lesions.

Summary

This paper deals with the effect of sulphur dioxide, ethylene and mixture of sulphur dioxide and ethylene on mango fruits with particular reference to the formation of lesions.

These gases were administered both to plucked fruits of some important varieties in the laboratory as well as in healthy orchards to fruits while still on the trees. The method of treatment of the fruits with gases was carried out either by giving a continuous current of desired concentration or by enclosing the fruits in containers with a fixed concentration for definite periods. Experiments variously devised, have been described.

Sulphur dioxide gas produces brick-red coloured lesions round the lenticels on the general surface of the fruit. Heavy doses produce large dark brown patches through the coalescence of these lesions. At low concentrations, the number and size of lesions per unit area are roughly proportional to the amount of sulphur dioxide gas administered and to the period of exposure of the gas. It has, however, been found that below a certain minimum concentration of the gas no lesions are produced even though the period of exposure be very much prolonged.

A certain degree of difference in varietal susceptibility to gas effects has been found in the different varieties.

With very low concentrations (4 : 10,000) under laboratory treatment, the fruits showed shrinkage of tissues at the tip accompanied by change of skin colour. The shrinking of tissues was uniformly spread with slightly heavier doses.

This condition of the affected fruits in no way resembles the 'Black-tip' disease of the mango fruit.

In the very young condition, the lesions develop with 16 : 1,52,000 concentration which soon coalesce giving the entire fruit dark colouration causing ultimate dropping off.

Ethylene in low doses (1 : 10,000) induces ripening while slightly heavier concentrations (10 : 10,000) produce brown coloured lesions around lenticels all over the skin of the fruit. The spots or lesions increased in size as heavier doses were given. These spots coalesced forming dark brown patches on the skin of the fruit. A concentration of 3 : 1,00,000 and 5 : 1,00,000 produced no effect whatsoever when administered even for very prolonged periods.

The effect of sulphur dioxide and ethylene in admixture on the fruits was evidenced by the formation of dark brown lesions. The treatment with low concentrations under laboratory conditions induced ripening, and usual lesions appeared.

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Literature Cited

*Allen, F. W. 1930. Proc. Amer. Soc.

*Bates, C. R. 1936. Report of the plant pathologist for the year ending December 31, 1935. Rep. Brit. S. Afr. Co., Mazoe citrus exp. Sta. (Abs. Rev. App. Myc. 16: 528–29, 1937).

*Biraghi, A. 1939. Alcune gravi lesioni prodotte da gas tossici su rami di Nocciolo. Boll. Staz. Pat. veg. Roma N. S., XNIII, 4, 497–508 (Ibid. 18: 561, 1939).

Crocker, William and Knight, L. I. 1908. The effect of illuminating gas and ethylene upon carnations. Bot. Gaz. 46: 259–75.

Das Gupta, S. N., Verma, G. S. and Sinha, S. 1941. Studies in the diseases of *Mangifera indica* Linn. Investigations into the effect of sulphur dioxide gas on the mango fruit. Proc. Ind. Acad. Sci. 13: 71–83.

Datta, R. L. 1944. Studies in the diseases of *Mangifera indica* Linn. A continuous method of administering gas in minute doses. Jour. Ind. Chem. Soc. 7: Nos. 3 & 4, 153–54.

*Denny, E. F. 1936. Effect of ethylene on respiration of Lemons. Bot. Gaz., 35.

*Dopp, W. 1931. Über die wirkung der Schwefligen Saure auf Blutenorgane. Ber. deutsch. Bot. Ges. 49: 173–221.

Effect of sulphur dioxide on vegetation — National Research Counil of Canada Ottawa, Canada, 1939.

*Girardin. 1864. Einfluss des Leuchtgases auf die Promenaden und Strassenbaume. Jahresber. Agrikultur. 7: 199–200.

Harvey, E. M. and Rose, R. C. 1915. The effect of illuminating gas on root systems. Bot. Gaz. 60: 27-44.

*Haselhoff, E. and Lindau, G. 1903. Die Bechadigung der vegetation durch Rauch Leipzig, Gebruder Borntraeger.

Katz, M., Ledingham, G. A. and McCallum, A. W. 1939. Effect of sulphur dioxide on vegetation, III. Symptoms of injury on Forest and crop plants. National Research Council of Canada, 51–76.

Katz, Morris and Lathe, F. E. 1939. Effect of sulphur dioxide on vegetation. National Research Council of Canada, 16. 441–42.

Lunge, G. and Ambler, H. R. 1934. Technical gas analysis. Gurney & Jackson, London.

Metcalfe, C. R. 1941. Damage to green-house plants caused by town fogs with special reference to sulphur dioxide and light. Ann. App. Biol. 28: 4, 310–15.

Ramsay, G. B. 1932. Sulphur dioxide injury of tomatoes. Phytopath. 22: 267–68.

Ranjan, Shri and Jha, V. R. 1940. The effect of ethylene and sulphur dioxide on the fruits of *Mangifera indica*. Proc. Ind. Acad. Sci. Sect. B. 11: 267–88.

*Regeimbal, L. C., Vacha, G. F. and Harvey, R. B. 1927. The effects of ethylene on the respiration of Bananas during ripening. Plant. Phy. 1927.

Romel, L. C. 1941. Localised injury to plant organs from hydrogen fluotide and other acid gases. Svensk bot. Tidskr. 30: 3, 271–86.

*Schroeder, Julius Von and Reuss, Gari. 1883. Die Beschadigung der vegetation durch Rauch und die oberharzer Hultenrauchschaden, Paul Parey, Berlin.

Sen, P. K. 1943. Black-tip disease of the Mango. Ind. Journ. Agri. Sci. 13: 3, 319–20.

*Setterstrom, C. and Zimmerman, P. W. 1939. Factors influencing susceptibility of plants to sulphur dioxide injury, 1. Contr. Boyce Thompson Inst. 10: 2, 155–81 (Abs. Rev. App. Myc. 18: 467, 1939).

Weirbact, L. A. 1926. The effect of sulphur dioxide upon plants: Methods of study. Amer. Journ. Bot. 13: 81–101.

Winston, J. R. 1937. Harvesting and handling Citrus fruits in the Gulf States. Fmr's. Bull. U.S. Dep. Agric. 1763. (Abs. Rev. App. Myc. 16: 744, 1937).

*Zimmerman, P. W. and Crocker, W. 1932. Sulphur dioxide injury to plants. Proc. Amer. Soc. 1930. 27: 51. Biol. Abs. E., 3482.

* Original papers have not been consulted.

THE HEPATIC VEGETATION OF PACHMARHI (MADHYA PRADESH) : A PRELIMINARY SURVEY*

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In Europe and America detailed systematic study of the hepatic flora of different territories has frequently been pursued. Such studies have often yielded useful and significant data on the distribution, migration, ecology, and other aspects of study connected with this interesting group of cryptogams. In India, however, the study of liverworts has not received enough attention with the result that our knowledge of the bryology of many parts of the country is yet very fragmentary. It was, therefore, thought advisable to make a critical study of liverworts of various parts of this country. With this object in view the senior author made extensive tours during the past 25 years or so and collected data and material from different territories throughout the country. Besides the material secured from these excursions we have also, at our disposal, a rich collection of the East Himalayan hepatics, made by Decoly and Schaul in 1897–99, as well as, some specimens collected by I. Pfleiderer (of Esslingen, Germany) from South India in 1912–14. Schiffner and Pandé (1950, p. 41) have communicated a preliminary paper based on the study of the former collection while Pandé and Bhardwaj (1949, pp. 15–27), Pandé, Bhardwaj and Ram Udar (1949, p. 9) and Pandé and Ram Udar (1950, p. 40) have added valuable information regarding some of the previously imperfectly known Indian species of liverworts. The present article gives a preliminary survey of the liverwort flora of Pachmarhi. In due course, it is the intention of the authors to present the results of their study of the hepatic vegetation of the various parts of the country.

Pachmarhi is the summer hill-station of Madhya Pradesh. It lies in 22° 28′ N and 78° 26′ E, on an isolated plateau in the Mahadeo Hills of the Satpura Range (Map). The town is situated about 32 miles South of Piparya station, the latter being 41 miles east of Itarsi, on Itarsi-Allahabad section of the Central Railway. There is a regular bus service between Piparya and Pachmarhi. The pleateau occupies an area of about 23 square miles and, on an average, has an altitude of just over 3,500 feet above sea level. It is cut off from the surrounding country by a number of hills and ravines except on the east from where it can easily be approached by the Piparya Road. The important

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Map of India showing the position of Pachmarhi in Madhya Pradesh

mountain peaks are, Dhupgarh (4,429 feet) on the west, Mahadeo (4,358 feet) and Chauragarh (4,303 feet) on the south.

Table I gives the climatic data of Pachmarhi. The annual rainfall is fairly heavy and, on an average, amounts to 79 inches, nearly the whole of which is precipitated between June and September. The soil is composed of gritty sandstone derived from thick ferruginous rocks constituting the Pachmarhi stage of the Upper Gondwanas (Jurassic). Out of the total area of 23 square miles, covered by the plateau, practically five-sixth is dominated by forest. Pachmarhi is noted for its streams and waterfalls, which encircle it on all sides. Some of these have a romantic and wild scenery. There are many cool swimming pools and beauty-spots along the streams where the rays of the sun, even in the month of June, would hardly penetrate. Some of the places, along these water-courses, are difficult to negotiate and a few, at places, are even dangerous. The main interest of a botanist lies in exploring these inaccessible places for flora.

Pachmarhi is an excellent place for botanical excursions and is not very distant from the Universities of the Uttar Pradesh and Madhya

TABLE I

Climatic data of Pachmarhi

(Height above mean sea-level 3528 feet)

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Annual
Mean daily maximum temperature in F°	72·0	75·3	84·1	91·9	95·8	87·8	76·5	74·8	77·5	79·3	74·5	71·3	80·1
Mean daily minimum temperature in F°	47·7	50·7	59·4	68·8	75·1	72·0	67·8	66·9	66·1	58·9	50·7	45·8	60·8
Highest maximum temperature recorded in F°	82	88	97	101	105	105	95	86	96	89	83	82	105
Lowest minimum temperature recorded in F°	30	31	38	48	59	60	61	59	55	44	36	30	30
Mean relative humidity % at 8 hrs. I.S.T.	65	55	40	32	38	71	91	93	86	63	60	65	63
Mean relative humidity % at 17 hrs. I.S.T.	47	39	25	21	24	61	86—	88	78	52	48	48	51
Average monthly rainfall in inches	0·64	0·67	0·56	0·37	0·62	9·04	26·23	23·82	14·19	2·30	0·74	0·43	79·61
Average number of rainy days	1·3	1·5	1·3	0·9	1·6	10·3	22·0	21·9	13·1	3·0	1·2	0·8	78·9
Maximum rainfall in 24 hours in inches	2·25	2·05	2·17	1·52	1·39	7·95	13·32	18·06	13·79	3·87	3·90	2·48	18·06
Mean daily wind velocity in miles per hour	2·4	3·1	3·5	4·2	5·3	6·2	7·?	6·4	4·4	2·3	1·9	1·8	4·1
Mean wind direction at 8 hrs. I.S.T.	S28W	S55W	N88W	N63W	N68W	N84W	W	N80W	N59W	N6E	S86E	S20E	N80W
Mean wind direction at 17 hours I.S.T.	N35W	N63W	N64W	N64W	N64W	N76W	N78W	N77W	N59W	N10E	N21E	N13W	N55W

Pradesh. Besides liverworts the region is also rich in ferns. Among the latter worth mentioning are *Alsophila glabra, Cyathea spinulosa, Angiopteris evecta,* and the royal fern of Britain, *Osmunda regalis.* Besides the ferns two other members of Pteridophytes *i.e., Equisetum debile,* abundant on the sides of Jambu Dwip stream, and *Psilotum triquetrum,* occasionally found on moist rocks, on the sides of Jambu Dwip stream near Chhote Mahadeo, are also met with.

The authors paid a visit to Pachmarhi in September/October 1951. About half a dozen localities were visited and an attempt has been made to make intensive collections from them.

As far as we are aware there is no record of the liverworts of this area in any of the earlier bryological publications of the country, *i.e.,* Mitten (1861–62), Kashyap (1922, 1932), Stephani (1900, 1906, 1906–09, 1909–12, 1912–17, 1925) and Chopra (1938, I and II). More than 20 years ago one of the authors (Pandé) paid a casual visit to Pachmarhi in the month of June and collected just a few species of liverworts, *e.g.,* Dumortiera, Marchantia, etc., from the side of a stream. A few years later a collection was made by Deokar and Bhatt and the specimens, including *Pallavicinia canaras* St., were sent to Pandé for identification. About a couple of years ago Misra from Saugar, together with some of his colleagues and students, made another attempt to collect liverworts from these hills. This collection, which was also sent to Pandé, contains some 6 or 7 species of liverworts.

On the basis of these collections, including our own, it may now be stated that about 32 species of liverworts, belonging to 23 genera distributed over 13 families, occur in this area. A few of the species are apparently new to science. This is only a preliminary survey and, considering the short time spent by us in these regions, the prospect of a better harvest should not be lost sight of. It is, therefore, proposed to explore this region more thoroughly in the near future.

Methods of Study

As far as possible taxonomic notes were made in the field at the time of collection. The observations were later supplemented by a study of the plants in the laboratory. Specimens for morphological study were properly cleaned and fixed on the spot, and, after washing them according to the nature of the fixatives, these were preserved in equal parts of 70 per cent. alcohol and pure glycerine. Type specimens are deposited in the Lucknow University Herbarium (Hepaticæ).

Taxonomic Account

In the list given below the arrangement of the orders is according to Evans' classification (1939, pp. 90–94) with the alteration that the Anthocerotaceæ have been placed at the head of the list and not at the end as has been done by Evans.

Systematic Enumeration of the Species Collected.

Order: *ANTHOCEROTALES*

ANTHOCEROTACEÆ

Anthoceros (L.) Prosk.

Anthoceros sp. Dicœcious. On moist ground and rocks. Pansy pool. Common. Probably a new species. 3960.

Anthoceros erectus Kash.—On moist ground and rocks. Dhoop-garh Road, near Pansy Pool. Common. 3961, 4241.

Phæoceros Prosk.

Phæoceros communis (St.) Schffn. et Pandé comb. nov.—On moist carth and rocks in very dense clusters near streams and pools. Chhote Mahadeo, Jambu Dwip, Dorothy Deep, Chhota Waterfall, Pansy Pool. Very common. 3006, 4237, 4240, 4263, 4389, 4392.

Notothylas Sulliv.

Notothylas indica Kash.—On moist ground and rocks. Mado Deo Caves. Less common. 4395.

Notothylas levieri Schffn.—On moist ground and rocks. Jambu Dwip, Chhota Waterfall. Less common. 2590, 4396, 4386.

Order: *JUNGERMANNIALES*

Sub-order: JUNGERMANNIACEÆ

CEPHALOZIACEÆ

Cephalozia Dumort.

Cephalozia sp.—Monœcious. On moist rocks. Jambu Dwip. Less common. 4246.

Chiloscyphus Corda

Chiloscyphus argutus Ness.—On moist ground and rocks. Jambu Dwip, Fairly common. 3002, 4278.

JUNGERMANNIACEÆ

Aplozia Dumort.

Aplozia sp.—On moist rocks, Chhota Waterfall. Less common. 3220, 3021.

Jungermannia L.

Jungermannia sp. I.—On moist soil, Jambu Dwip, Dorothy Deep, Fairy Pool. Very common. May be a new species. 3022, 3024, 4955.

Jungermannia sp. II.—On moist earth. Jambu Dwip, Pansy Pool. Less common. 3162, 4949.

Jungermannia humilis Kash.—On moist earth. Twynam stream. Less common. 3028.

RADULACEÆ

Radula Dumort.

Radula perrottettii G.—On moist rocks. Near Pansy Pool. 3160.

LEJEUNEACEÆ

Lejeunea Libert.

Lopholejeunea (Spruce) Schffn.

Lopholejeunea sp.—On moist rocks. Pansy Pool. Very rare. It resembles *Lopholejeunea æmula* Schffn. to some extent but only a few sterile specimens have been collected and it is not possible to decide its specific identity definitely. 3029.

Rectolejeunea Evans

Rectolejeunea aloba (Sande Lac.) St.—On moist ground and rocks and bark. Jambu Dwip, Chhota Waterfall, Pansy Pool. Common. This liverwort was first recorded from India by Pandé and Misra (1943, pp. 159-69) from the Eastern Himalyas and South India where it grows on leaves. 2598, 3031, 3938, 4948, 4953.

Microlejeunea (Spruce) St.

Miscrolejeunea sp.—On moist rocks on way to Pansy Pool. Common. This is identical with an epiphyllous species collected by Pandè from Jog Falls (W. Ghats) and Darjeeling. The sterile nature of the specimen makes the determination of the species uncertain. 3163.

Leptocolea (Spruce) Evans

Leptocolea sp.—On moist rock, Pansy Pool. Rare. 3035.

Sub-order: METZGERINEÆ

FOSSOMBRONIACEÆ

Fossombronia Raddi

Fossombronia himalayensis Kash.—On moist soil, rocks and exposed ground. Twynam Stream, Jambu Dwip, Mado Deo, Dorothy Deep, Chhota Waterfall, Fairy Pool, Inspection Bungalow, etc. Very common everywhere. 2558, 2561, 2562, 2571, 2572, 3036, 3037.

PALLAVICINIACÆ

Pallavicinia S.F. Gray

Pallavicinia canaras St.—In moist places, on moist rocks, and along the streams. Sometimes it is associated with *Dumortiera hirsuta* (Sw.) R. Bl. et Nees and *Riccardia levieri* Schffn.—Abundant on the sides of practically all the streams, waterfalls, and gorges. Twynam stream, Chhote Mahadeo, Jambu Dwip, Mado Deo, Dorothy Deep, Chhota Waterfall, Fairy Pool, Pansy Pool. Very common. 3014, 3016, 3084, 3543, 3569, 3571, 3940, 5182, 5419.

Riccardiaceæ

Riccardia S.F. Gray

Riccardia levieri Schffn.—On moist rocks near streams. Twynam Stream, Jambu Dwip, Dorothy Deep. Fairly common. 2966, 2595, 2596, 3008, 3011, 3642, 5047.

Riccardia sp.—Very much like *Riccardia indica* St. On moist rocks near Pansy Pool. Only a few sterile thalli could be collected. Rare. 5317.

Order: *MARCHANTIALES*

Marchantiaceæ

Marchantia (March. f.) L.

Marchantia nepalensis L. et L.—On moist rocks. Jambu Dwip, Chhota Waterfall. Common. 3056, 3063, 4640.

Marchantia palmata Nees.—On moist rocks. Jambu Dwip, Chhota Waterfall. Common. 3560, 4639.

Dumortiera R. Bl. et Nees.

Dumortiera hirsuta (Sw.) R. Bl. et Nees.—On moist rocks and moist soil. Chhote Mahadeo, Jambu Dwip, Twynam Stream, Chhota Waterfall, Pansy Pool. Very common. 2817, 2821, 2849, 3005, 3527, 3538, 5154.

Rebouliaceæ

Reboulia Raddi

Reboulia hemispherica (L.) Raddi.—On moist ground and moist rocks. Jambu Dwip. Not very common. 2859, 4638.

Asterella Beauv.

Asterella blumeana Nees.—On way to Pansy Pool and Patharchatta. On moist ground. Rare. 4637.

Asterella angusta St.—On moist and dry ground and rocks, walls of buildings and exposed places. Chhote Mahadeo, Jambu Dwip, Dorothy Deep, Twynam Stream, Dhoopgarh, Pansy Pool. Very common. 2819, 2896, 3004, 3062, 3916, 3972, 3973, 4646, 5054.

Plagiochasma L. et L.

Plagiochasma appendiculatum L. et. L.—On moist and dry ground, rocks and walls of buildings, etc. Chhote Mahadeo, Jambu Dwip, Dorothy Deep, Chhota Waterfall, Fairy Pool. Very common. 2591, 3671, 3968, 3992, 49884, 5356.

Plagiochasma intermedium L. et G.—On moist soil. Jambu Dwip. Common. The plants are monœcious as well as diœcious. In one monœcious specimen female receptacle is borne on an innovation and male receptacle at the junction of the shoot with the main thallus. In another monœcious specimen male receptacle is placed behind the female receptacle. Rare. 3549, 4983.

Targioniaceæ

Targionia (Mich.) L.

Targionia hypophylla L.—On moist soil and rocks. Twynam Stream, Jambu Dwip. Common. 3012, 4985, 4986, 4994.

Cyathodium Kunze

*Cyathodium barodæ** Chavan.—On moist soil and rocks. Chhote Mahadeo, Jambu Dwip, Waterfall. Common. 3980, 3981, 3984, 3986, 4987.

Ricciaceae

Riccia (Mich.) L.

Riccia discolor L. et L.—On moist soil and rocks. Chhota Waterfall and Mado Deo. Common. 3558, 3985.

Riccia gangetica Ahmad.—On moist soil and rocks. Cantonment area, Dorothy Deep. Common. 4988.

Riccia fluitans L.—On very moist soil and on the side of streams and actually under water. Jambu Dwip. Common. 3158.

Conclusions

The Pachmarhi plateau lies in the heart of the sub-continent of India and has, more or less, favourable conditions for the growth of liverworts. On the plateau itself only a few liverworts, *i.e.*, Riccia, Asterella, Plagiochasma, Fossombronia grow, while in the gorges and the sides of the streams, where there is enough shade and moisture, the flora is fairly rich.

As will be evident, from a perusal of Table II, out of the total of 32 species, so far known from Pachmarhi, 20 are common to the Western Himalayas, 17 to Eastern Himalayas, 21 to South India, while 13 of these occur in many other parts of the country. A few of the species, apparently new to science, are confined to Pachmarhi. Thus in this region there occurs an admixture of the species of the Ghats and the Himalayas. Pachmarhi thus forms a meeting ground for the hepatic flora of the Himalayas and South India.

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* According to Schiffner *C. barodæ* Chavan is a synonym of *C. smaragdinum*.

TABLE II

Name of species	Pachmarhi	Western Himalayas	Eastern Himalayas	South India
Anthoceros sp.	×	..	..	..
Anthoceros erectus Kash. ..	×	×	×	×
Phæoceros communis (St.) Schffn. et Pandé comb. nov. ..	×	×	×	..
Notothylas indica Kash. ..	×	×	..	×
Notothylas levieri Schffn. ..	×	×	×	×
Cephalozia sp.	×	..	..	..
Chiloscyphus argutus Nees. ..	×	×	×	×
Aplozia sp.	×	..	..	..
Jungermannia sp. I	×	..	..	..
Jungermannia sp. II	×	..	..	..
Jungermannia humilis Kash. ..	×	×	..	..
Radula perrottetii G.	×	..	×	×
Lopholejeunea sp.	×	..	..	..
Rectolejeunea aloba (Sande Lac.) St.	×	..	×	×
Microlejeunea sp.	×	..	×	×
Leptocolea sp.	×	..	..	..
Fossombronia himalayensis Kash.	×	×	..	×
Pallavicinia canara St. ..	×	..	..	×
Riccardia levieri Schffn. ..	×	×	×	×
Marchantia nepalensis L. et L. ..	×	×	×	×
Marchantia palmata Nees. ..	×	×	×	×
Dumortiera hirsuta (Sw.) R.Bl. et Nees.	×	×	×	×
Reboulia hemispherica (L.) Raddi.	×	×	×	×
Asterella blumeana Nees. ..	×	×	..	×
Asterella angusta St.	×	×	×	×
Plagiochasma appendiculatum L. et L.	×	×	×	×
Plagiochasma intermedium L. et G.	×	×	..	..
Targionia hypophylla L. ..	×	×	×	×
Cyathodium barodæ Chavan. ..	×	..	..	×
Riccia discolor L. et L. ..	×	×	×	×
Riccia gangetica Ahmad. ..	×	×	..	..
Riccia fluitans L.	×	×	×	×

Note.—× indicates presence of species.

Development, for providing us valuable facilities during our stay at Pachmarhi. To Dr. S. K. Parmanik, M.Sc., Ph.D. (London), Deputy Director, Meteorological Laboratory, Poona, we are grateful for placing at our disposal the data concerning the climatology of the place.

Literature Cited

Chopra, R. S. 1938 *a*. Notes on Indian Hepatics, I. South India. Proc. Ind. Acad. Sci. 7 B (5): 239–51.

———. 1938 *b*. Notes on Indian Hepatics, II. Sikkim-Himalayas and Bengal. Ibid. 8 B (6): 427–39.

Evans, A. W. 1939. The classification of Hepaticæ. Bot. Rev. 5: 49–96.

Kashyap, S. R. 1929. Liverworts of the Western Himalayas and the Punjab Plain, I. Lahore.

——— and Chopra, R. S. 1932. Ibid. II. Lahore.

Mitten, W. 1860–61. Hepaticæ Indiæ Orientalis. Jour. Proc., Linn. Soc., 5. (18): 89; (19): 109.

Pandé, S. K. and Bhardwaj, D. C. 1949. On some liverworts new to Indian Flora. Jour. Indian Bot. Soc. 28: 15–27.

———, ——— and Ram Udar. 1949. South Indian Hepatics I. Late Abs. Proc. 38th Indian Sci. Congr., Allahabad, 9.

——— and Misra, R. N. 1943. On the epiphyllous liverworts of South India and Ceylon. Jour. Indian Bot. Soc. 22: 159–69.

——— and Ram Udar. 1950. South Indian Hepatics II. Proc. 37th Indian Sci. Cong., Poona, 40.

Schiffner, V. 1938–39. Monographie der Gattung *Cyathodium*. Ann. bryol. 11: 131–40, 12: 123–42.

——— and Pandé, S. K. 1950. On the East Himalayan Hepatics I. Proc. 37th Indian Sci. Cong., Poona, 41.

Stephani, F. 1900–25. Species Hepaticarum. Vols. I–VI. Génève.

SOME OBSERVATIONS ON THE FLORAL BIOLOGY OF SWEET POTATO

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The sweet potato [*Ipomœa batatas* (L.) Lam.] is commonly propagated by cuttings from the previous crop. Sometimes sprouts or "draws" obtained from tubers are also used for this purpose. The plant does not generally produce flowers. When it does bloom the flowers seldom mature into fruits and give viable seeds. This habit of dominant vegetative growth and non-production of seeds is admittedly a serious handicap in planning any programme of improvement of this crop by breeding. It is therefore necessary as a first step, to collect as much information as possible on flowering and floral biology of sweet potato.

Although the amount of literature on sweet potato is quite extensive, studies on the floral biology of this plant are comparatively few. Stout (1924; 1926) has stated that sweet potato flowers and forms seeds freely in the West Indies, the Hawaii and the Philippines. In other parts of the world where flowering occurs, seed formation is often promoted where opportunities of cross pollination are available.

Thompson (1925) studied the floral biology of sweet potato and found that the flower buds of sweet potato open during the night and remain so until noon of the next day. On cloudy days the flowers remain open for a longer period, and the time of closing of the flowers depends largely on the atmospheric conditions and the season.

Sugawara (1940) succeeded in inducing flowering in three varieties of sweet potatoes from Japan by growing them in nutritional solution (water culture) in green-house conditions. He concluded that the ability to produce flower and set seed is a varietal character because two other varieties treated in identical conditions did not produce any flower or seed.

Miller (1937–41) made a series of studies on the production of flowers in sweet potato. According to him, the day length, humidity and certain optimum temperature, favours the production of flowers. One of the suggestions made by Miller for inducing flower production is to allow the vines to grow on the trellis for two successive seasons. This was tried at Delhi and encouraging results were obtained. Other workers on the subjects are Tioutine (1935), Akimoto (1939), Edmonds *et al.* (1946), and Mikell *et al.* (1948).

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Over fifty different varieties of sweet potatoes collected from India and other countries have been grown at the Indian Agricultural Research Institute, New Delhi, for the last four years. Out of these, only one variety called G.T. 6 flowered profusely. A few other varieties also formed flower buds, but the buds either did not open or the number of flowers produced were too few for experimental purposes. Therefore, the present study of the floral biology was largely restricted to the variety called G.T. 6.

Anthesis.—The flower buds are borne in clusters of 7–10, rarely more. The inflorescence is a cyme with regular hermaphrodite flowers. The first sign of opening of the flower is marked by the appearance of a few slits in the calyx. The sepals gradually separate out exposing the petals which begin to grow at a fast rate. The sepals also grow simultaneously and they attain their maximum size on the day of opening of the flower. The petals are at first light green and then they develop a tinge of pink and finally they are predominantly pink or purple. The corolla tube takes nearly two hours to open completely from the inflated bud stage. The floral buds are very sensitive to atmospheric temperature. A cold spell invariably delays the opening of the flower buds. The optimum temperature for flower opening appears to be around 70°–72° F., while the minimum temperature required is 52° F. Young buds took 13 to 15 days to open in November and 16 to 18 days to open in December. It was also noticed that when the change of temperature is too sudden, it retards further development.

Opening of flowers was observed every two hours for a week in December. It was found that for recording purposes the intervals of two hours were suitable. The result is given below:—

TABLE I

Time of opening of flowers

No. of flowers open

Date of observation	4 A.M.	6 A.M.	8 A.M.	10 A.M.	12 A.M.	2 P.M.	4 P.M.	6 P.M.	8 P.M.	10 P.M.	12 P.M.	Total No. of flowers
12-12-1949	..	..	..	4	4	9	1	..	..	..	..	18
13-12-1949	6	4	3	2	4	5	..	..	..	..	..	24
14-12-1949	2	8	1	3	4	6	..	..	..	..		24
15-12-1949	3	5	4	3	4	5	2	..	..	..	..	26
16-12-1949	2	4	3	5	5	7	..	..	..	..	..	26
17-12-1949	4	7	3	6	3	3	..	..	..	..	..	26
18-12-1949	6	7	3	5	5	5	..	..	..	..	..	31
19-12-1949	6	8	3	4	6	4	..	..	..	..	..	31
	29	43	20	32	35	44	3	..	..	..	..	206

TABLE II

Meteorological data during the period 12–19*th December* 1949

Date of observation	Temperature in Farenheit		Relative humidity in percentage	Remarks
	Maximum	Minimum		
12-12-1949	67·5	42·1	57·0	..
13-12-1949	72·0	49·8	60·5	..
14-12-1949	72·7	42·0	59	Traces of rain 11–12 A.M.
15-12-1949	70·6	40·4	49·5	..
16-12-1949	70·6	39·8	44·5	..
17-12-1949	72·7	42·1	50·0	..
18-12-1949	72·0	41·9	42·0	..
19-12-1949	71·6	42·9	49·0	..

It will be evident from the above two tables that with a slight rise in temperature the number of flowers opening in the early part of the morning increases. There are two peak periods of opening of the flowers every day, one, between 4 A.M. to 6 P.M. and the other between 12 A.M. and 2 P.M. It was further observed that buds which are half open at 2 P.M. do not open any further till early next morning (*i.e.*, 4 A.M. to 6 A.M.). These observations suggest that under Delhi conditions, flowers do not open either in the evening or at night. Thompson's observation is however different. According to him (*l.c.*) the flowers of sweet potato open during the night and remain so until noon of the next day. Humidity seems to play a less important part but high humidity and traces of rain delay the closing of flowers.

Dehiscence of anthers and pollen.—The dehiscence of anthers starts from top downwards. Anthers usually dehisce after two hours of opening of the flower. Only in 6 per cent. of the cases the anthers were found dehiscing simultaneously with the opening of the flowers. It was observed that with higher humidity the dehiscence is hastened.

Pollen fertility is variable. Observations on the pollen size and fertility were made during November and January and data obtained are given below:—

It will be seen from the above table that the higher fertility is generally associated with the small size of the pollen grains. It was also interesting to observe the great variability of the pollen grains within the same anther. This may have some bearing on the high polyploid nature of sweet potato plant. The chromosome number

is $2n = 90$, while the basic number for the genus *Ipomæa* is believed to be only 15.

TABLE III

Pollen size, frequency and fertility

Date of observation	Range of pollen grain size	Frequency	Per cent.	Percentage of fertility
I 4 to 8th November 1949	(*a*) 83·3–96·3 'μ'	32	14	76·5–81
	(*b*) 103·2–119·9 'μ'	132	59	
	(*c*) 132·2–149·9 'μ'	70	27	
	Total no. of pollen grains	234		
II 17 to 20th January 1950	(*a*) 83·3–93·3 'μ'	136	53	100
	(*b*) 100–109 'μ'	112	43	
	(*c*) 118 'μ'	8	4	
	Total no. of pollen grains	256		

Under normal conditions the pollen fertility is very high although there is no production of seeds. In order to find out whether this sterility is due to genic or physiological causes, bud pollination, hand pollination, and open pollination were done but without any appreciable result as shown below:—

TABLE IV

Date of pollination	(A) Bud pollination		(B) Hand pollination		(C) Open pollination	
	No. of buds pollinated	No. of fruit set	No. of buds pollinated	No. of fruit set	No. of flowers observed	No. of fruit set
10–12–1949 ..	42	Nil	55	Nil	93	Nil
21–1–1950 ..	25	Nil	60	Nil	48	Nil

It therefore appears that the variety G.T. 6 is self-sterile. Tioutine working at Sukhun (U.S.S.R.) (*l.c.*) has however succeeded in obtaining viable seeds in four cases out of 320 self-pollinated flowers. Pollen tube studies were also made but without any success as indicated below:—

It is difficult to ascribe any cause to the failure of germination of pollen tubes on the stigma without further studies of changing the environmental conditions. Sigemura *et al.* (1938) and Akimoto (1939) obtained seeds by providing a photo-period of 8–10 hours daily during

TABLE V

Pollen tube studies

Details	Examined after no. of hours of pollination															
	3				6				18				24			
	Time of pollination															
	8	9	10	11	8	9	10	11	8	9	10	11	8	9	10	11
1 No. of fertile pollens on the stigma	4	8	10	2	2	4	6	1	1	3	1	..	..	1	1	..
2 No. of germinated grains	Nil				Nil				Nil				Nil			
3 No. of pollen tubes that has reached ovary	Nil				Nil				Nil				Nil			

the flowering season, and by cross fertilisation respectively. Stout (*l.c.*) has already suggested that when opportunities of cross fertilisation are available, there are better chances of obtaining seeds. Further work on these lines may be worthwhile.

Other observations.—The flowers remain on the pedicel for a short time. The fading of the flowers takes place after 10 to 30 hours of opening. The petals first begin to lose their colour and fade away. The fading proceeds down to the base. By this time the shining stigma loses its lustre and begins to dry up. Later on, it turns brown. The flower drops off from the pedicel after 24 to 30 hours of opening. Under Delhi conditions the following varieties flowered: G.T. 6, Jullunder 3, *Pamna* and Ranger. Flowering begins from the basal end of the cluster and as many as three flowers in the same cluster were seen to open on the same day. In G.T. 6, the flowering continued from the middle of October 1949, to the first week of February 1950. A second flush of a few flowers was again seen from the middle of April to the middle of May. The flowers of sweet potato are very sensitive to touch and small injury. It was observed that even half opened flower buds stopped further opening when the corolla tube was cut for taking records of dehiscence of anthers.

SUMMARY

1. Observations taken in Delhi on the floral-biology of a variety of sweet potato called G.T. 6 have been given. Optimum temperature for flower opening is 70°–72° F. During November, it took 13 to 15 days to open a flower from the young bud stage, while in December it took 16 to 18 days.

2. It was found that there are two peak periods of opening of the flowers, one between 4 A.M. to 6 A.M. and the other between 12 A.M. to 2 P.M.

3. Flowers were not observed to open at night.

4. Pollen grains are variable in size even within the same anther. Although the flowers of sweet potato do not set fruits in Delhi, the pollen fertility is very high, *i.e.*, 76·5 to 100 per cent.

5. Plants appear to be self-sterile.

References

Akimoto, S. 1939. Some experiments on hastening flowering in sweet potato. Agric. Hort. 11: 993–98 (*Plant Breeding Abstract* No. 1448 ; 15: 1945).

Edmond, J. B. and Martin, J. A. 1946. The flowering and fruiting of the sweet potato under green-house conditions. Proc. Am. Soc. Hort. Sci. 47: 391–99.

Mikell, J. J., Miller, J. C. and Edmond, J. B. 1948. Flowering of the Jersey type sweet potato. Science. 107: 628.

Miller, J. C. 1937. Inducing sweet potato to bloom and set seed. J. Hered. 28: 347–49.

———. 1939. Further studies and technic used in sweet potato breeding in Louisiana. Ibid. 30: 485–92.

———. 1941. Breeding sweet potato for table, stock and starch. Proc. 42nd Annual Convoc. S. agric. Workers, Atlanta, Ga. 158–59.

Sigemura, T., Takahasi, T. and Kakihara, K. 1938. Sweet potato breeding by seeds with artificial induction of blooming. Proc. Crop. Sci. Soc. Jap. 10: 281–96.

Stout, A. B. 1924. The flowers and seed of sweet potato. J. New York bot. Gard. 25: 153–68.

———. 1926. Further notes on the flowers and seeds of sweet potato. Ibid. 27: 129.

Sugawara, T. 1940. Inducing the flowering and the fruiting of sweet potato by water culture. Japanese J. Bot. 10: 335–42.

Thompson, J. C. 1925. Production of sweet potato seedlings at the Virgin Island Experimental Station. Viragin Island Sta. Bull. 5: 10.

Tioutine, M. G. 1935. Breeding and selection of sweet potato. J. Hered. 26: 3–10.

SOME NOSTOCACEÆ FROM UTTAR PRADESH

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The present communication deals with certain new forms of Nostocaceæ collected in the course of an investigation on the algal-flora of the river Barna in Banaras District. One new species, and three new forms are being described here.

Genus *Cylindrospermum* Kütz.

1. *Cylindrospermum sphaerica* sp. nov. (Figs. 1–4)

Plant mass soft, mucilaginous, pale-brown and forming a mat. Trichomes single, curved, often entangled with each other. Cells barrel-shaped, constricted at the septa. Heterocysts sub-conical to ellipsoidal, rounded at the distal end, one at each end of the trichome. Spores spherical, sub-terminal, at both ends of the trichomes, formed singly, occasionally in pairs, the sub-terminal one maturing first. Thick, smooth, golden brown exospore and thin, smooth and hyaline endospore.

Lat. trich., 4·8–5·6 μ; long. cell, 4–8 μ (mostly 4·8 μ); lat. het., 4·8–5·6 μ, long. het., 7·2–11·2 μ; crass. (diam.) spor., 16–19·2 μ.

Habitat:—On soil, submerged in water along with *Cylindrospermum stagnale* forma *variabilis* and *Cylindrospermum licheniforme* Kütz.

The distinctive feature of this alga is the presence of perfectly spherical spores, in which respect it differs from all species of the genus *Cylindrospermum* so far reported. On account of the smooth walls of its spores, however, it can be placed in Section II of the genus, accordingly to the key given by Geitler (*cf.* Geitler, 1932, p. 815). It approaches *Cylindrospermum licheniforme* Kütz. in the dimensions of its cells and heterocysts, but differs from it in the variable shape of the latter, the shape and size of the spore and the colour of the spore-wall. With *Cylindrospermum muscicola* Kütz., the present alga agrees in the size and shape of the cells and the golden-brown colour of the spore-wall, but it differs from the same in the shape of heterocysts, and the shape of the spores which are also formed occasionally in pairs.

2. *Cylindrospermum stagnale* (Kütz.) Born. et Flah.

Geitler, in Rabenhorst's *Kryptogamen-Flora Von Europa*, Band XIV, Cyanophyceæ, 1930–32, p. 816, Fig. 520 C. Forma *variabilis* Forma nov. (Figs. 5–8).

FIGS. 1–13

Figs. 1–4. *Cylindrospermum sphaerica* sp. nov. Fig. 1. Filament with a young developing spore. Fig. 2. *a–d*. Variations in the shape of the heterocysts. Fig. 3. Twin spores (immature). Fig. 4. End of a trichome with a mature spore. Figs. 5–8. *Cylindrospermum stagnale* (Born. et Flah.). forma *variabilis* forma nov. Figs. 5–7. Variations in the shape of heterocysts. Fig. 8. Trichome end with a spore. Figs. 9–13. *Wollea Bharadwajae* Forma. nov. Fig. 9. Single vegetative mature filament in the sheath. Fig. 10. Part of a trichome with geminate spores on both sides of the heterocyst. Fig. 11. Portion of a trichome with three mature spores in a chain. Fig. 12. Part of trichome outside a sheath showing apical cell. Fig. 13. Several trichomes enclosed in a sheath.

(Magnifications: Figs. 1, 9, 10 & 13, × 425; rest ×890).

Plant mass soft, dense, mucilaginous, light blue-green, forming a mat. Trichomes single, blue-green, often entangled with each other. Cells cylindrical or quadratic, slightly constricted at the septa. Heterocysts at both ends of the filaments, varying in shape—narrowly cylindrical,

sub-elliptical or almost ellipsoidal, with elongated bacteria attached. Spores elongate, sub-cylindrical, broader at the heterocyst end, and flattened slightly on the sides, formed singly, sub-terminally, with a thick hyaline exospore and a thin, colourless endospore.

Lat. cell, 4–4·8 μ, long cell, 6·5–8 μ; lat. het., 5·6–6·4 μ, long. het., 9·6–16 μ; lat. spore, 16·4–17·6 μ, long. spore, 29–32 μ.

Habitat:—On soil, submerged in water, along with *Cylindrospermum sphaerica* sp. nov. and *Cylindrospermum licheniforme* Kütz.

The form differ from the type in having slightly broader cells and variable shape of heterocysts.

Genus *Wollea* Bornet et Flahault.

3. *Wollea Bharadwajae* Singh.

Singh, R. N., 1942, "*Wollea Bharadwajae* sp. nov. and its Autecology", *Ann. Bot.*, N. Ser., Vol. 6, No. 24, p. 593–606, Figs. 1–20.

Forma (Figs. 9–13).

Lat. trich., 5–5·8 μ; long. cell, 4·8–6·4 μ; lat. het., 6–7 μ; lat. spor., 10–12 μ; long. spor., 12–12·8 μ.

Habitat:—Floating in water along with *Nodularia spumigena* Mertens, *Spirogyra submaxima* Transeau, *Hydrodictyon reticulatum* Lagerheim, and vegetative *Pithophora* sp.

The form differs from the type in having broader trichomes and smaller spores which are also formed in rows of two or three on either side of the heterocyst.

Genus *Anabæna* Bory

4. *Anabæna vaginicola* Fr. and Rich.

Fritsch, F. E., and Rich, F., 1929, "Contributions to our Knowledge of the Freshwater Algæ of Africa, VII," *Trans. Roy. Soc., S. Africa*, 18, p. 87, Figs. 74–75.

Forma *Fertilissima* forma nov. (Figs. 14–17).

Plant mass soft, pale-green, entangled with angiospermic roots, interspersed in the thallus of *Vaucheria* sp. Trichomes shining blue-green, rarely free, commonly one or several enclosed in a common diffluent mucilage sheath. Cells quadratic or barrel-shaped, constricted at the septa. Heterocysts barrel-shaped, slightly flattened at the apices. Spores ellipsoidal, developed centripetally, in long chains; sporulation commencing away from the heterocysts, but gradually progressing towards them, often the whole filament becoming sporogenous. Spores, sometimes, placed obliquely or transversely in the filament.

Lat. cell, 4–8·5·6 μ, long. cell, 3·2–5·6 μ; lat. het., 6·6–7·2 μ, long. het., 5·5–6μ; lat. spore, 6·4–8μ, long. spor., 11·2–13·4μ.

FIGS. 14–17

Figs. 14–17. *Anabæna vaginicola* forma *fertilissima* Forma. nov. Figs. 14 & 15. Single fertile filaments enclosed in sheath. Fig. 16. Several filaments enclosed in a common sheath. Fig. 17. Single naked trichome with an apical cell.
(Magnifications : Fig. 17, × 890 ; rest × 425.)

Habitat:—In water, interspersed in the thallus of *Vaucheria* sp.

This form differs from the type (*Anabæna vaginicola* Fr. and Rich.) in the centripetal development of the spores and also in the whole trichome sometimes becoming sporogenous.

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LITERATURE CITED

1. FRITSCH, F. E. AND RICH, F. 1929. Contributions to our Knowledge of the Freshwater Algæ of Africa, VII. Trans. Roy. Soc. S. Africa, 18, 1-92.

2. GEITLER, L. 1932. Cyanophyceæ, Rabenhorst's Kryptogamen Flora von Europa, 2nd Ed., Band XIV.

3. SINGH, R. N. 1942. *Wollea Bharadwajae* sp. nov. and its Autecology. Ann. Bot., N. Ser. 6, No. 24, 593-606.

SOME UNREPORTED MUTATIONS IN *CICER ARIETINUM* L.

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Introductory

It is well known that several distinct agricultural types exist in *Cicer arietinum* L. with marked differences in the colour, shape and size of their leaves, flowers, pods and seeds. Work on the classification of the existing types of Indian gram was commenced as early as 1915 when Howard, Howard and Khan described 24 types of it with separate coloured plates. Shaw and Khan revised this work in 1931 describing as many as 84 types including some mutants. About the same time Dixit (1932) found a mutant which he named *Cicer gigas* but which is regarded only as a type—Type No. 79—by Shaw and Khan. Dixit subsequently described two more types—the 'Kabuli' and 'Desi' (1932). More recently Ekbote (1937) found two mutants, *viz.*, the 'simple leaved' and the 'tiny leaved' and Ramanujam and Singh mentioned one more in 1945.

The Indian gram, however, has been found to be far more mutable than any other economic crop plant and yet new types are occasionally evinced. An effort is made here to describe in brief a few unreported mutant forms spotted in *Cicer* during the course of plant breeding work at Dharwar and Bail-Hongal in the Bombay State.

1. *A mutant with alternate leaflet arrangement.*—It is common knowledge that the leaves of the *Chickpea* are oddpinate compound bearing pairs of leaflets placed opposite or subopposite; rarely, as recorded by Howard, Howard and Khan (Figs. SL_1, SL_2, A_{10} in coloured plate, 1915), some of the leaflets in a type may be found to be alternately arranged on the midrib. The peculiarity of this new mutant form is, however, that its short stalked leaflets, which hardly open out to exhibit their entire ventral surface are mostly and distinctly alternately placed, the leaves being rather stiff and straight, the main branches of the plant tending to converge at the top. The plant has thus a distinct appearance and can be easily identified as a distinct morphological type.

The plant is about 9″ to 12″ in height standing on a round main stem about 7 mm. in diameter which, at a height of about 2″ from the ground level, divaricates into two to three main branches and several secondary branches all over. The leaves measuring about 30 × 16 mm. bear mostly 9 serrated leaflets, each 8–10 × 6 mm. in size, alternately, and sparsely and rather irregularly arranged on the midrib. The internodes are about 10 mm. long. The leaves are stiplulate and terminate

into three or four irregularly placed leaflets thus rendering the type another distinguishing character. On an average a plant of this type bears about 120 pods, each measuring 17 × 10 mm. and containing a yellowish brown wrinkled seed about 9 × 6 mm. in size. The type matures within about 97–100 days from its germination.

FIG. 1. *Left.*—A branch of the mutant with alternate leaflets
Right.—A branch of a normal type

The study of a cross between this mutant and a normal leaved strain 'Dohad' revealed that the difference between the two types of leaflet arrangement was monogenic.

The mutant was spotted at Dharwar in 1943 in a crop raised from unimproved local seed and has been thence breeding true for the characters described above.

FIG. 2. Pure lines of the mutant with long branches

2. *A mutant with long branches.*—This mutant is typically distinct for its branching habit. The plant is about 8″ to 9″ in height, has a round stem about 5 to 6 mm. in diameter and divaricates almost from the ground level. It throws out sideways mostly four or rarely five to six very long lateral branches, each about 15″ to 18″ in length,

running almost parallel to the ground. It has a few or almost no secondary branches and appears almost four sided from above.

The long branch has 18 to 20 leaves each about 40 × 21 mm. in size and having 13 to 17 subopposite leaflets measuring 10 to 11 × 7 to 8 mm. The internodes, 12 to 15 mm. in length are evidently longer than in a normal type (10 mm.) a plant hardly producing 50 to 60 pods on an average. The pod is about 20 mm. in length and 10 mm. in breadth and contains a wrinkled seed with a jet black testa measuring 10 × 6·5 mm. The flower, 9 × 9 mm., is pink in colour.

FIG. 3. *Left.*—A branch of the 'giant' type
Right.—A branch of a normal type

This mutant was traced in a normal black seeded type grown at Dharwar in 1946 since when it is found to breed true for its almost trailing habit. It is an early type maturing in 90 days from its germination.

3. *The 'giant' type.*—This unusual type differing from Dixit's *Cicer gigas* was discovered in a crop of gram raised from an unimproved local seed on the Government Farm at Arbhavi (Bombay State) in 1945 since which time it is producing similar progeny.

FIG. 4. *Left.*—A branch of the mutant with fascicular leaflets
Right.—A branch of a normal type

The plant grows to a height of about 15″ to 18″, is more or less erect and has a round stem about 10 mm. in diameter divaricating into two or three main branches each having one or two secondary branches. The internodes are about 20 mm. long. Its compound leaf is pinnate, subopposite and stipulate, the leafy stipules being very prominent. The leaf bears on an average 14 to 18 large, broad serrated leaflets each measuring about 20 × 15 mm. The leaflets are ovate in shape and are crowded, each often overlapping the adjoining one. The flower is large, 10 × 11 mm. in size and pink in colour, that of a normal type being about 8 × 8 mm. The pod is large, rather constricted on the ventral side and measures 28 × 17 mm. on an average as against that of the normal type (17 × 11 mm.). The seed is dark brown and wrinkled, often with a dark patch on the testa, measuring 11·5 × 7·5 mm., the seed in a normal type being about 9 to 10 × 6 to 7 mm.

It is a late maturing type taking about 120 days from its germination and is a very shy bearer producing only 10 to 12 pods per plant.

FIG. 5. *Left.*—A branch of the bold mutant
Right.—A branch of a normal type

4. *A mutant with fascicular leaflets.*—This type somewhat resembles Ekbote's 'tiny leaved mutant' in its panicled or loose clustered leaflets borne on the compound pinnate and stipulate leaf; yet it differs from the latter in several aspects. The plant has a weaker stem divaricating at ground level, and tends to droop to the ground. In this plant too, it is found that the main midrib branches into secondary and tertiary midribs on which are borne obovate leaflets measuring 15 × 8 mm. as against the lanceolate ones of the 'tiny leaved' mutant measuring 7·25 × 3·08 mm. The dentation at the apex of the leaflets and the serration of the lobed leafy stipules is very distinct. As in the 'giant type' described above the pod in this type also is unusually large, about 25 × 17 mm. in size, distinctly different from the medium sized pod of the 'tiny leaved' mutant. The carpel has a prominent venation on both sides of the suture and contains a wrinkled seed measuring about 11 × 7 mm., a major portion of the carpel remaining unfilled.

This true breeding mutant was traced in a cultivator's field at Bailhongal (Bombay State) in 1948.

5. *A bold mutant.*—A plant in a crop of 'Chafa' gram grown at Dharwar in 1944 was found to have enlarged vegetative and reproductive parts and has been producing similar progeny ever since. The stem of this type is round and thick about 9 mm. in diameter, the leaflets (10 × 8 mm.) are thicker and broader, and the flowers (11 × 9 mm.), pods (22 × 13 mm.) and seed (11·5 × 8·5 mm.) are all bolder than those of a normal type, the internodes (10 mm.) being comparatively shorter. The plant grows semierect to a height of about 14″ to 16″ branching at about ½″ to 1″ from the ground level.

The foliage of the type is dark green with a bluish tinge; the leaflets, 13 to 15 on a leaf, have prominent serration and are densely placed on the midrib, thus reducing the length of the leaf. The flower is bluish pink in colour, the seed being wrinkled brown. This type is also a shy bearer, producing about 45 pods per plant, many of the flowers failing to set pods.

A large number of crosses tried between this mutant and some normal types at Dharwar failed to set from which fact, and also from its enlarged vegetative and reproductive parts, it appears likely that it may happen to be a tetraploid or a polyploid type. In the field this vigorous type can easily be identified from other normal types.

The chromosome number of this mutant form is yet to be determined.

The 'normal type' referred to for comparison throughout this paper is the strain No. 18 to 12 evolved by the Bombay Agricultural Department.

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References

1. Argikar, G. P. 1952. Occurrence and Inheritance of 'filicoid' form in *Cicer arietinum* L. Curr. Sci. 3: 76–77.

2. Chavan, V. M. and Argikar, G. P. 1950. Three new economic types in Bengal Gram. Indian Farming. 11-12: 539–40.

3. Dixit, P. D. 1932. Studies in Indian Pulses — A note on the cytology of 'Kabuli' and 'Deshi' gram types. Indian J. Agri. Sci. 2: 385–90.

4. ————. 1932. Studies in Indian Pulses — A case of gigantism in gram. Ibid. 2: 391–408.

5. EKBOTE, R. B. 1937. Mutations in Gram. Curr. Sci. 5: 648–49.

6. ————. 1942. Genetics of two mutations in Cicer. Indian J. Genet. Pl. Breed. 2: 50–56.

7. HOWARD, A., HOWARD, G. L. C. AND KHAN, A. R. 1915. Some varieties of Indian gram. Mem. Dept. Agric. Bot. Series. 7: 213–35.

8. KADAM, B. S. 1945. New strains for old crops in Bombay, II. Cereals, Pulses and Oilseeds. Indian Farming. 6: 403–07.

9. ————. 1945. Chafa — A new variety of gram for Bombay. Ibid. 6: 444–46.

10. RAMANUJAM, S. AND SINGH, H. 1945. Narrow leaf — another mutation in gram. Indian J. Genet. Pl. Breed. 5: 46–50.

11. SHAW, F. J. F. AND KHAN, A. R. 1931. Some varieties of Indian Gram (*Cicer arietinum* L.). Mem. Dept. Agric. Bot. Series. 19: 27–47.

REVIEWS

Principles of Plant Physiology. By Bonner, J. and Galston, A. W. 1952, Pp. vii + 499. Price $ 5.00.

Biology: Its Human Implications. By Hardin, G., 1952, 2nd Ed. Pp. xii+720. Price $ 5.00.

General Genetics. By Srb, A. M. and Owen, R. D. 1952, Pp. x+561. Price $ 5.50.

Published by W. H. Freeman & Company, San Francisco and California.

There have appeared in recent years many text-books on plant physiology, but most of them are either too advanced or too elementary for the Bachelor of Science students of Indian Universities. Bonner and Galston's "Principles of Plant Physiology" is just the book that would meet the requirements of our B.Sc. students. Avoiding detailed discussions of contradictory views and extensive tables, it gives a clear account of the basic principles of plant physiology in the light of modern knowledge. For those who may desire to have a more detailed knowledge of any aspect of the subject, there are given at the end of each chapter references to the important recent reviews and other literature. The chapters on growth and development, which form Part III of the book, are particularly striking for the originality of treatment. The whole book is well illustrated with bold and clear diagrams.

Hardin's book approaches the subject of biology from a completely anthropomorphic angle. It elucidates all the fundamental principles of biology from the study of man himself. That makes the book most interesting. Laws of heredity and evolution form an important part of the book. Reference to other groups of plants and animals and principles of classification is made only in connection with the great drama of evolution of which the emergence of man forms the final act.

Srb and Owen's "General Genetics" is a most stimulating text-book giving an up-to-date account of a very rapidly progressing branch of biology. Each chapter is followed by references to the important literature and a large number of questions and problems. The latter greatly help in the understanding of the subject. The last three chapters deal with the application of genetics to plant breeding, improving animal productivity and human welfare.

A. C. J.

Agriculture and Animal Husbandry Research, 1929–1946, Part II. Edited By U. N. Chatterjee and issued by the Indian Council of Agricultural Research, New Delhi, 1952. Pp. 190. Price Annas 8.

This is a brief review of the various investigations in the fields of agriculture, animal husbandry, veterinary science and dairying that have been carried out in India under the ægis of the Indian Council of Agricultural Research from 1929 to 1946, that is from the year of inception of the Council to the advent of Independence in the country. Of special interest to botanists are chapters 2nd to 17th and 25th to 27th, which deal with various farm crops and plant diseases. The cost of the monograph is nominal.

A. C. J.

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